Identification and remediation countermeasures of the Agriculture water problem in Qilu lake basin

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Abstract: In this paper, based on the characteristic of natural geography, hydrometeor, ecological environment and the development of economic and society on the Qilu Lake Basin, making full use of a lot previous data, including field measured data, investigation data, planning reports and historical materials, to study and analyze the evolution population, arable land, irrigation area, agricultural planting, the water surface of lake of Qilu Lake since 1280 A.D. The test was carried out in the variation trend of Qilu Lake’s precipitation, average temperature, relative humidity, reference crop evapotranspiration, water resources, and other factors during 1950~2016. The results show that water resources shortage phenomenon of Qilu Lake Basin can be traced back to 400 years ago. Social progress and increasing population have promoted the continuous improvement of the agricultural replanted pattern, the large consumption of water resources and the pollution of agricultural non-point sources have caused the deterioration of the water environment of the Qilu Lake. Additionally, lake water appears three times greatly atrophy was caused by the reclaiming land from lakes and climate warming, and the fragility of water ecology is intensifying. The integration of resources should be combined with the system of lake-leader, then taking some measures like that saving water and reducing wastewater, reducing agricultural replanting index, delineation of ecological red line and management and protection of water coastline, water trans-valley project form other river basin, allocation of water resources and monitoring and control of water resources and so on. The adoption of these measures will gradually repair the water ecology, improve the water environment, improve the carrying capacity of water resources, and realize the green and beautiful countryside.

1. Introduction
Data from the past half century show that a rise in global temperature of 1°C has resulted in a 3%~12% reduction in maize production and a 3%~9% reduction in wheat production, which is beneficial to rice production in middle and high latitudes, but will lead to a reduction in rice production in low latitudes. Irrigation can effectively reduce the negative impact of high temperature on crop yield \textsuperscript{[1]}. The impact of global climate change on different fields and regions, such as agriculture, water resources, and ecosystems in southwest China, is generally more harmful than profit. The total amount of water resources has decreased, the frequency and intensity of drought and flood disasters have increased, the demand for industrial and agricultural production and living water has increased, resulting in an increase in the gap between supply and demand of water resources. The operational risks of major water conservancy projects have increased, and the degree of eutrophication in plateau lakes has increased.

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According to the principle of "seeking benefits and avoiding harms", research on vulnerability and adaptability should be carried out, crop planting structure and layout should be adjusted, multiple cropping index should be improved, off-season vegetables and fruits should be developed, biotechnology and information technology should be integrated, agricultural and ecological disaster risk prevention and control technologies should be developed, water resources in arid and semi-arid areas should be developed and utilized efficiently, and technologies for rational allocation and optimal scheduling should be promoted, so as to promote the realization of water-food-ecological integrated technology system for adaptation to climate change [2, 3]. As an important part of the terrestrial hydrosphere and the global water cycle, lakes have the functions of regulating regional microclimate, regulating and storing river runoff, providing drinking water sources, irrigating farmland, shipping, breeding aquatic animals and plants, maintaining biodiversity and tourism landscape [4]. Since 2000, the area of major lakes in the country has shown an increasing trend, but 94.1% of the lakes in the Yunnan-Guizhou plateau region have shrunk due to less precipitation, with a change rate of 2.12km²/a. Temperature and precipitation are the important driving forces for the shrinkage of lakes [5]. Over-exploitation of lakes has led to environmental deterioration, ecological imbalance, conflicts between industries in the region and other problems [6].

Qilu Lake is one of the most prominent lakes with water supply problems in the central Yunnan Plateau. Population expansion and unreasonable agricultural water use methods have resulted in water shortage of resources, large shrinkage of lake area, deterioration of water environment, siltation and so on, accelerating the decline of the lake. A recent analysis of sediment grain size, loss on ignition, pigment, diatom and other indicators revealed that the nutrition level of Qilu Lake was not high before 1916, and the total chlorophyll and cyanobacteria pigment content increased significantly in 1960s and continued to this day. Eutrophication of water body was the main factor driving the succession of diatom community structure. Degradation of aquatic plants, hydrological conditions and climate change had a superimposed effect on the construction of diatom community [7]. In the process of the national long-term plan for ecological civilization construction, the implementation of strategic deployment and important infrastructure such as river length system and lake length system, and the construction of water diversion project in central Yunnan, the study and analysis of agricultural water problems in Qilu Lake Basin will provide basic basis for the restoration and management of lake water ecology and the comprehensive utilization and management of water resources.

2. Materials and Methods

2.1 Data Used
(1) The monthly (or daily) precipitation, average temperature, highest temperature, lowest temperature, sunshine hours, relative humidity and average wind speed sequence from the establishment of Tonghai County Meteorological Station in Qilu Lake Basin to 2016; The monthly water level, evaporation, discharge and water quality data of Qilu Lake from 1960 to 2016; Monthly water level and discharge observation data from the construction of 7 hydrological stations in Qujiang River Basin, including Daxiqiao, Xishan and Majiazhuang, which have been built and are currently being built. (2) Yuxi City and Tonghai County's Social and Economic Statistical Yearbook 1949-2016, Water Resources Bulletin 2000-2016, Water Conservancy Yearbook, Land Use Survey (the "Second Dispatch" Database), Military Topographic Map since 1960s, etc. (3) The Records of Water Conservancy in Yunnan Province, the Records of Tonghai County, the Records of Historical Flood and Drought Disasters in Yunnan Province (1911 Three Years Before the Xuantong Period of Qing Dynasty) and other local historical documents. (4) China Gaofen 2 (GF-2) Satellite Remote Sensing Data.

2.2 Calculation Method
The Mann-Kendall test method was used for trend test of hydro-meteorological observation time series. Penman- Montieth equation model was used for reference crop evapotranspiration (brief note: ET0). MIKE BASIN simulation model was used for water resource system configuration. For detailed
3. Identification of Agricultural Water Problems in Qilu Lake Basin

3.1 Extreme shortage of water resources in Qilu Lake Basin

Qilu Lake is a closed shallow plateau lake with an average water depth of 4.0m and a volume of 168 million m$^3$. The basin covers an area of 359km$^2$, involving 7 towns and 20 villages in Tonghai County of Yuxi City. It has a total population of 275,300 and a total cultivated land area of 227,600 mu. It is the main vegetable planting base in Yunnan Province with a land reclamation rate of 42.3%. The per capita GDP is 32,100 yuan RMB per person, and per capita net income of farmers is 15,540 yuan, which is 1.12 and 1.89 times of the average level in Yunnan Province respectively.

Qilu Lake has no obvious natural water outlet. It discharges water from the karst cave in the southeast of the lake. It was blocked after the 1970 Tonghai earthquake, with an over-flow of only 2.20 ~ 3.00m$^3$/s. In the rainy season, the lake's water outlet was not smooth, resulting in flooding of lakeside farmland. In 2004, a new flood discharge tunnel was manually excavated, which flowed into Qujiang River through the high and large area of Lishan Mountain with a designed flow rate of 8.0m$^3$/s. The average annual precipitation of the basin is 876.6mm. The total water resources after deducting evaporation from the lake surface is 47.91 million m$^3$. The average water resources per capita are only 172m$^3$/person, belonging to the water crisis area where water resources are extremely scarce. There are only 4 small (1) type reservoirs, 26 small (2) type reservoirs and 109 small ponds in the Qilu lake basin, with a total storage capacity of 14.966 million m$^3$ and a small diversion well project. As shown in fig. 1, the actual water supply capacity of the water conservancy project is 85.019 million m$^3$. The development and utilization of water resources in the basin have reached 86.4%, and the development of shallow groundwater is 64.7%, both of which have far exceeded the reasonable upper limit of 40%.

Figure 1 Schematic Layout of Water Network Project in Qilu Lake Basin
The total amount of natural water resources in Qilu Lake Basin is obtained through runoff reduction.
analysis, as shown in Figure 2(a). In the 61-year time series from 1956 to 2016, there are four consecutive dry year groups, 1958-1960, 1979-1982, 1987-1989, 2009-2012, and four wet year groups, 1964-1973, 1983-1986, 1994-2004, 2014-2016. According to historical data and documents such as "Tonghai county annals" and "Kangxi tonghai county annals", the population in the basin is verified\textsuperscript{[9-12]}, and the changing trend of per capita water resources in Qilu lake basin since Ming hongwu thirty-one years (1398 A.D.) is analyzed as shown in fig. 2(b). Over the past 600 years, the per capita water resources in Qilu Lake Basin has been declining in a straight line, falling below the water balance line before 1398 A.D., continuing to fall into water shortage areas in 1620 (the 48th year Wanli Era of Ming Dynasty), and further sliding into water crisis water shortage areas around 1920 (the 19th year of the Republic of China). After the founding of New China, the common people lived and worked in peace and contentment, the social productivity was released to the maximum extent, the rapidly increased population, the vigorous development of industrial and agricultural economy consumed a large amount of water resources, and the current situation dropped to 172 m\textsuperscript{3}/ person (Note: frequent large earthquakes, wars and famines that connected with the sea from the late Qing Dynasty to the early Republic of China greatly reduced the population in the basin, and the per capita water resources increased slightly).

![Figure 2 Water Resources Change Trend in Qilu Lake Basin](image)

3.2 Qilu Lake Water Pollution Problem Becomes Increasingly Serious

The current situation of Qilu Lake Basin is that only sewage outlets above the scale entering the river are those of Tonghai County Sewage Treatment Plant, with a registered annual discharge of 200,000 t of waste water. Since 1980s, the water quality and eutrophication degree of Qilu Lake have become increasing serious. In the past 6 years, the water quality has been stable to the poor V category. The main pollution factors are TN and COD, which are moderately eutrophic lakes. The water quality of the rivers entering the lake has been in poor category V for a long time, but COD is lower than the water quality of the lake body, TN and TP are higher than the water quality of the lake body. From 1982 to 2016, the monitoring data of Qilu Lake water quality showed that\textsuperscript{[8,9,11-13]}, TN, the main pollutant, rose from 1.22mg/L to 5.08mg/L, with a concentration increase of 3.13 times. COD increased from 5.034mg/L to 16.09mg/L, the concentration increased by 2.20 times. BOD increased from 2.26mg/L to 8.85mg/L, and its concentration increased by 2.92 times. Chlorophyll a increased from 39.95mg/m\textsuperscript{3} to 145.17mg/m\textsuperscript{3}, the concentration increased by 2.63 times. The transparency fluctuated between 0.3 and 1.0m, and the concentrations of TP and NH\textsubscript{3}-N did not change much.

According to the analysis of Gaofen-2 satellite remote sensing data and the annual report of agricultural economic statistics, the current crop structure in Qilu Lake Basin is dominated by economic crops such as Chinese cabbage. The structure is relatively single, with 4-7 seasons of planting each year, extensive water management and large loss of chemical fertilizer. The application amount of agricultural chemical fertilizer in the whole basin is about 50,000 t/year. The effective utilization rate of chemical fertilizer is less than 50%. A large amount of unused chemical fertilizer is lost or left in the soil. The accumulation amount of basic ions gradually increases after soil nutrient accumulation in the vegetable
field, and the soil pH value increases after irrigation by lake water with high saline-alkali content. The alkali-hydrolyzable nitrogen content reaches 276.7 mg/km, and the effective phosphorus and available potassium are 110.63 and 253.29 mg/kg respectively \[14\]. Inflow into Qilu Lake has become the main factor affecting the water quality of the lake. NH3-N currently entering the lake is mainly generated by rural and urban life, contributing 45.7% and 36.3% respectively. TN and TP are mostly produced by agricultural cultivation, contributing 67.1% and 81.1% respectively. The sources and contributions of COD\text{cr} are agricultural planting, rural life, livestock and poultry breeding and urban life, accounting for 26.8%, 24.7%, 17.5% and 12.1% respectively.

Tonghai county town has not yet formed a complete domestic sewage collection pipe network system. The drainage system of the town is basically a combined system of rain and sewage. The sewage along the coast has not yet been cut off around the lake. Some of the sewage directly enters the lake, which has a great impact on the water quality of the lake. Due to long-term sedimentation, the polluted sediment of Qilu Lake is distributed in the estuary of the lake. The sediments of 0~0.2m in the surface layer of the lake bottom are grey-black organic sludge, and excessive N and P are collected to cause cyanobacteria to grow and die and then deposit. From 0.2 to 1.5m, it is brown-red iron clay, and human activities accelerate soil erosion to flow into lakes to form high-speed sediments. 1.5~2.0m is gray organic matter, calcareous clay or organic matter stucco; Heavy metals Cd and Cr are enriched and gradually increase from deep layer to shallow layer \[15\]. Dissolved organic nitrogen in sediment reached 72.26 mg/kg and amino acid was 14.90~25.78 mg/kg \[16\]. After 1957, a large area of lake reclamation, lake shrinkage and sediment into the lake resulted in an increase in the bottom of the lake, and the swamping of the west became more and more serious. The total sediment volume of the polluted sediment is about 10.24 million m\(^3\), and the content of organic matters such as total phosphorus and total nitrogen in the sediment is high. When the sediment is disturbed or the water quality is improved, the pollutants contained in the sediment will be released into the water body, causing water pollution and damage to benthic habitats. In the past, in order to ensure the irrigation and flood discharge on both sides of Qilu Lake Basin, most river courses were rebuilt into concrete or masonry impervious embankments, which destroyed the habitats of animals and plants in the water-land ecotone along the lakeside and adversely affected the habitats and ecological functions of rivers and lakes. Land use in Qilu Lake Basin is shown in Figure 3.

3.3 Lake water ecosystem tends to be unitary and pollution-resistant

In the 1957 survey, the water quality of Qilu Lake was good. In addition to the general Malay eye vegetables, sphaerophytes, small algae, waterwheels, and caries, there were a large number of algae plants, such as seaweed, etc\[17\]. The 1976 survey showed that there were 39 species of vascular plants in Qilu Lake, with high density of aquatic plant communities. The ecological transition structure of emergent plants-wet plants-submerged plants was complete. The main species were Zizania caduciflora, Azolla-Sophora japonica, juniper, water plasters, Myriophyllum spicatum, Potamogeton malayi, verticillata, Sophora alopecuroides, cauliflower and other communities, which were distributed on 70% of the lake surface of Qilu Lake \[11\]. In 1982, slight pollution began to occur in Qilu Lake. The sea lettuce gradually disappeared in the lake, and the verticillata community disappeared. Bitter grass remained only in the channel. Malayan eyeballs, leafy eyeballs and water plasters did not formed a community. The pollution-resistant foxtail algae has become the dominant species in the whole lake. Potamogeton crispus and Redline grass form a community. The community of Zizania latifolia has expanded greatly, and the juniper was distributed in a belt shape \[11\]. By 2009, the original aquatic plant community in Qilu
Lake had basically disappeared. The dominant groups were pollution-resistant Potamogeton konjac, Potamogeton malayi, Sophora alopecuroides, etc. The growth and decline of water hyacinth changed the physical, chemical and ecological environment of the water body \[19, 20\]. Zooplankton increased gradually with lake eutrophication, from 550~652 /L in 1950s to 4012~6344/L in 1980s \[13\]. The original 11 kinds of indigenous fishes in the lake, such as Yunnan carp, Cyprinus ilariaeformis, Qilu white fish and Datou carp, have been replaced by foreign species such as crucian carp and carp. The community structure of algae in Qilu Lake has changed to take pollution-resistant species in blue and green algae as dominant species, and the biomass of a single dominant species was large and the diversity index was low. The 2010 survey found no benthic animals, only a small number of oligochaeta. The diversity of zooplankton gradually decreased, the dominant species changed from rotifers to copepods, and the indicator species of eutrophic water body was becoming the dominant species. Uplift plants were distributed in lumps, submerged vegetation withers away in large quantities, and ecological functions are gradually lost.

3.4 The lack of river and lake shoreline management makes the lake encroached and nibbled away.

The current coastline of Qilu Lake is about 45km in length. According to the Regulations on the Protection of Qilu Lake in Yunnan Province, the Qilu Lake water body and the highest water level within 100m along the surface extension are Qilu Lake Class I protected areas, which are demarcated and marked by Tonghai County People's Government. The Secondary protected areas are runoff areas other than primary protected areas. Qilu Lake was formed in the Tonghai rift basin and is higher in elevation than the surrounding Xingyun Lake and Fuxian Lake. It is an erosive lake. The ancient coastline represented by gastropod snail shell accumulation reveals that the oldest and highest ancient coastline of Qilu Lake is consistent with the edge of bedrock basin. Due to the seismogenic structure of the Tonghai earthquake, the ancient lake surface inclines northward, and the southern bank of the ancient...
coastline at the same time is higher than the northern bank. According to local historical records, previous studies and topographic mapping results, comprehensive analysis shows the changing trend of lake water surface, cultivated land and irrigated area of Qilu Lake since the Yuan Dynasty to the 21st year of Yuan Dynasty (A.D. 1284). Over the past 730 years, Qilu Lake's water surface has shrunk three times. From 1284 to 1386, Mongolians stationed troops in Tonghai Basin and advocated "developing water conservancy and planting wasteland". They brought into the Central Plains an advanced irrigation tool, Mulonggu Waterwheel, to carry water. In 100 years, the lake area has decreased by 25.7 km², with a shrinking rate of 0.25 km²/year. The second time was from 1938 to 1967 AD. After digging sea mud and reclaiming land during the Republic of China period and the large-scale lake reclamation movement during the Great Leap Forward period in New China, the area of Qilu Lake was reduced by 31.3 km² and the shrinkage rate was 1.08 km²/year in 30 years. The third time was from 2010 to 2015 AD, the southwest region suffered from a catastrophic drought for four consecutive years. Coupled with a large amount of groundwater pumped from lakeside farmland for irrigation, the lake's water supply fell short of its income. The water area shrank to 21.7 km², a sharp decrease of 14.5 km² and a shrinking rate of 2.90 km²/year in five years. From the comparison of figs. 4(a) and 4(b), it can be seen that every lake shrinkage has become a period of a sharp increase in cultivated land and irrigated area in the lakeside area due to the phenomenon of "water retreating and people advancing". Moreover, the shrinking time of these three lakes is shorter and shorter, the shrinking speed is faster and faster, and the signs of fragile water ecology, aging of lakes and decline are extremely obvious.

![Figure 4 Changes of Lake Area and Cultivated Land Resources at Qilu in Recent 700 Years (A: Lake Water Area; B: cultivated land and irrigated area)](image)

3.5 Regional Climate Change Accelerating Qilu Lake's Decline

The Mann-Kendall test was used to judge the statistical variation trend of main meteorological factors in different time scales such as year and season from 1960 to 2016 in Qilu Lake (Tonghai Station). The results are shown in Figure 5. Precipitation is slightly increasing in both annual and seasonal time scales. Only in autumn is it still slightly decreasing. Although it has experienced a decline period lasting 10 years since 2003, the continuous abundant water period since 2013 has eased the long-term change trend a lot, showing a certain periodicity. The average temperature increases and warms in spring, summer, autumn, and winter, reaching that significant level \( \alpha = 0.01 \). Compared with 1960s, the first six years of 2010s are warming except April, with the warming rate of 0.032–0.279 °C/10a in each month and 0.057–0.153 °C/10a in spring, summer, autumn, and winter, with the largest increase in summer and autumn. The relative humidity is a downward trend, but only the interannual and summer and autumn reach significant level \( \alpha = 0.01 \), and the regional drying trend is obvious. The wind speed tends to decrease, reaching a significant level only in winter. Taken together, the reference crop evapotranspiration (brief note: \( ET_0 \)) reflected in the agro-meteorological environment is generally a decreasing trend, but there was an obvious turning point change in 2001, i.e. the trend was gradually decreasing from 1960 to 2000. While it has been gradually increasing since 2001, which means that the
current transpiration and evaporation water consumption of the same plant increased by more than 18.2% compared with 2000. Therefore, it is the superposition effect of extra-low water years with less rainfall and runoff for four consecutive years from 2009 to 2012, coupled with the continuous rise of temperature and reduce of humidity, and the continuous increase of industrial and agricultural water consumption in the basin, that makes Qilu Lake's water inflow decrease sharply, evaporation and utilization consumption increase under the comprehensive influence, resulting in a significant decrease in lake water storage, water level drop and serious shrinkage of lake area.

Figure 5 Variation Trend of Main Meteorological Factors in Qilu Lake (A: Annual Average Temperature; B: annual average $ET_0$)

4. Countermeasures for Agricultural Water Problem

4.1 Basin Water Saving and Emission Reduction Strategies

In view of the severe situation of extremely scarce water resources and water pollution prevention and control in Qilu Lake Basin, the strictest assessment standard for water conservation in industrial and agricultural production and living should be implemented. According to the model of ecological water-saving irrigation area, the water-saving and emission-reduction plan for watershed agriculture and its recent implementation plan will be formulated, the construction of agricultural high-efficiency water-saving demonstration irrigation area will be carried out, agricultural water-saving irrigation technologies such as drip irrigation will be vigorously promoted, and the agricultural planting model will be changed. Phase-out high water consumption and high pollution industries and prohibit the addition and introduction of high water consumption enterprises. Implementation of light industry and chemical industry water-saving transformation demonstration project, the key construction content is water-saving technological transformation, water-saving new technology promotion, ecological ponds, and waste water purification and reuse.

By 2020, it is planned to implement the farmland water saving and pollution reduction project in the farmland near Qilu Lake, to carry out fine management of irrigation and drainage system, and to realize water saving in farmland irrigation. In Qilu Lake near the lake high-intensity agricultural non-point source pollution control unit, the farmland weight loss and efficiency enhancement project will be implemented. Through the promotion of environment-friendly controlled release formula fertilizer, carbon-vinegar slow release formula fertilizer, organic liquid full nutrition formula fertilizer, demonstration of scientific fertilizer and water management knowledge, the promotion of efficient water saving, fertilizer saving and water and fertilizer integration technologies, the implementation area is 32,000 mu. Supporting the construction of an environment-friendly fertilizer station service center.

The implementation of the village environment comprehensive improvement project aims at the collection and disposal of domestic sewage and the collection, removal and disposal of domestic garbage in villages along the northeast coast of Qilu Lake Basin. 37 new sewage treatment systems with a total treatment scale of 2445 m$^3$/d; The newly-built village has 7,243 m of sewage interception ditches, 54,326
m of pipelines, 107,986 m of household branch pipes, 206 rainwater grates, 84 sand settling wells, 1,826 inspection wells, 5 inverted siphons and 26 overflow wells. There are 108 garbage bins, 20 garbage bin trailers, and 20 cleaning tools.

According to the plan of fine allocation of water resources in Qilu lake basin, sewage collection and treatment along the lake and sewage interception projects are planned and implemented. For the construction of sewage interception network along the lake in the east, west and north bank, a certain ecological reservoir volume is built through ecological sewage interception ditches and reservoir systems to intercept and regulate the initial rainwater. The intercepted rainwater stays in the reservoir for 3-5 days, so that the pollutants carried by the plant can be absorbed as much as possible. After the water body is properly purified, it is supplemented to the irrigation water distribution system through the water resource recycling project, thus realizing the comprehensive utilization of urban tail water and farmland irrigation backwater and greatly reducing the inflow of farmland non-point sources into the river (lake). The demonstration project of Wu wenwei et al. In the 61 wetland area to purify farmland drainage through the aquatic canna-substrate wetland system of "trash-blocking regulation pond+ enhanced sedimentation pond+ Multi-medium infiltration system" shows that the removal rates of TN, NO\textsubscript{3}-N, NH\textsubscript{4}-N, COD and TP have reached 55.94%, 50.0%, 40.07%, 60.63% and 40.0%, respectively, and the pollutant content removed by canna harvesting is 23.2kg/a of total nitrogen and 2.6 kg/a of total phosphorus\textsuperscript{[24]}.

4.2 Restriction on Agricultural Replanting Index

According to historical documents, socio-economic statistics and the planning and design results of the "water diversion project in central Yunnan", the changes of agricultural planting structure in Qilu lake basin from 1900 to 2040 are analyzed as shown in fig. 6. The Qilu Lake Basin has good water source conditions and abundant light and heat land resources. The influence of the Central Plains civilization has promoted the development of farming culture and production technology. The population density around Qilu Lake reached 190 people/km\textsuperscript{2} during the Ming and Qing dynasties. Food consumption is a top priority, with food crops as the main crop. Literature data\textsuperscript{[9,11,12]} show that during the 50 years from 1900 to 1950, the proportion of rice (mid-season rice) in the crops in Da Chun was above 80%. While the small spring crops were mainly broad bean and wheat, with planting proportions of 60%~70% and 25%~30% respectively. It continued until the early days of reform and opening up in 1980. After the implementation of the contract responsibility system with remuneration linked to output in rural areas, farmers have spontaneously demanded benefits from the land, the proportion of rice and other food crops with large input of labor and other means of production and relatively low output benefits has greatly decreased, and the planting areas of flue-cured tobacco, vegetables (spring and autumn) and other cash crops have increased dramatically. Especially after 2010, in accordance with the thought of "people are not idle while the land is idle", the vegetable rotation pattern is generally "cauliflower-leek-cabbage-lettuce", "cabbage-celery-lettuce-cauliflower" and "Chinese cabbage-celery-leek-lettuce". The multiple cropping index gradually rises to more than 300%, increasing the output benefit of cultivated land to 17,000 yuan/mu, resulting in increased non-point source pollution of cultivated land\textsuperscript{[25]}. The investigation and study showed that\textsuperscript{[26-29]}, the amount of compound fertilizer, urea, calcium superphosphate and other kinds of chemical fertilizers applied in each season (stubble) such as cabbage, cauliflower and lettuce planted in the dam area was 270~600kg/ mu, and the use of pesticide increased to about 300t year by year. The concentrations of TN, TP and COD\textsubscript{x} in the drainage area of Qilu lakeside farmland are 413.32, 10.78 and 1305.60 t/a respectively. Every year, about 380,000 t of field waste vegetable leaves are produced in the whole Qilu Lake basin, and the components of nitrogen, phosphorus, COD\textsubscript{x} and BOD\textsubscript{5} produced after decay will reach 265.2, 4.9, 8012.3 and 2725.4t, which are the main sources of pollutants entering the lake in the basin.
In the planning period from now on to 2040 level years, the number of continuous cropping of vegetables or multiple cropping of vegetables and other grain cash crops in one year should be strictly controlled within 4 times, and the economic benefits of crops should be improved by promoting different cropping patterns such as intercropping of sweet corn with different vegetables (bandwidth 2.3m)\textsuperscript{[30]}, vegetables-barley-flue-cured tobacco\textsuperscript{[31]}, and allowing time for water and soil resources in the basin to rest. According to the requirements of the construction of beautiful countryside, through factory process control and fine management, the "four-in-one" ecological agriculture mode is implemented, and renewable energy (biogas and solar energy), protected cultivation (pollution-free greenhouse vegetables), solar greenhouse cultivation (pigs, chickens and other livestock and poultry) and sanitary toilets are rationally allocated to realize a virtuous cycle of energy, water, fertilizer and product logistics. With the "near lake high intensity agricultural non-point source pollution control unit" as the main carrier, we will comprehensively promote the reform of agricultural cultivation mode in the river basin, try out the agricultural collectivization development mode, take the village group as the core, establish the agricultural industry development group. The villagers will take a stake in the industrial group according to their cultivated land quantity, land output efficiency, etc. Delineation of different economic crop cultivation areas, exploration of agricultural non-point source centralized control mode and method, optimization of the spatial pattern of agricultural industry in the basin, zoning to develop access mechanisms.

4.3 Watershed Ecological Red Line Control

From the perspective of ecological civilization construction, the development concept of "green water and green mountains are golden mountain and silver mountain" is implemented. The reasonable water surface rate and its ecological service value in the whole basin are analyzed and calculated. Combined with the needs of lake water supply, flood control, ecological environment restoration and improvement, the reasonable lake ecological water level and ecological environment water demand are studied and determined. Through water level regulation, the water ecological landscape in the area around the lake is realized, which lays the foundation for the improvement of tourism and human settlement environment. At the same time, the water ecological red line of Qilu Lake should be demarcated according to the basic requirements of the special tasks of deepening the reform and deployment of the central government\textsuperscript{[32, 33]}, such as ecological red line, river length system, lake length system, etc. Only by spatial control of the protection and utilization scope of the water shoreline, can the unification of multiple regulations be realized, the lake body be prevented from being occupied artificially, and the
health of rivers and lakes be maintained, can the decline and fall process of Qilu Lake be delayed.

Qilu Lake's water function area is divided into development and utilization areas, including agricultural, industrial, landscape and fishery water use areas. The water quality protection target in 2020 is Class IV in the near future and will be raised to Class III in 2030. The planned Qilu Lake National Wetland Park covers an area of 138.8km², accounting for 96.9% of the area of rivers, lakes, swamps and constructed wetlands [34]. Three red lines for the development and protection of Qilu Lake Basin in response to climate change are studied and delineated: 113.3km² for basic farmland protection area, 44.82km² for urban construction land and 184.38km² for ecological red line area for building ecological barriers in the basin, accounting for 33.1%, 13.1% and 53.8% of the basin area respectively [35]. The pattern of "mountain-water-forest-field-lake-grass" water ecological environment protection in Qilu Lake has been basically formed. The water and soil loss situation has been effectively controlled. The water ecological environment of rivers entering the lake has been further improved. The lakeside wetland ecology has been effectively restored. Biodiversity has been protected. The mechanism of clear water production and flow in rivers entering the lake has been further restored. The ecological compensation mechanism has been gradually established and perfected. The integrated restoration system of river basin land and lake water ecology has been comprehensively constructed.

Qilu Lake is in a state of serious organic pollution, especially in the western bay, where TN concentrations in sediments and water bodies are higher in the periphery of the lake, lower in the center of the lake and higher in the southwest than in the northeast, while TP is increasing from southwest to northeast [36]. We should carry out sediment dredging in marshy areas and flooded areas of water hyacinth in the southern part of Qilu Lake, promote the restoration of submerged plants in the dredged areas, and promote the transformation of Qilu Lake into a benign grassy lake. The water hyacinth in Qilu Lake should be fully recovered to remove the internal pollution and take effective measures to control the spread of water hyacinth. Planning and implementation mainly into the lake estuary coastal area of polluted sediment dredging, dredging 5 million m³; The reed, hyacinth and wild rice straw in the lake were harvested, salvaged and disposed of as resources, with a total area of 4,000 mu of harvested plants, forming a normal salvage and management mechanism.

4.4 Adding Water to External Watershed to Increase Water Resources Carrying Capacity

In order to cope with extreme weather events such as drought and flood caused by regional climate change, it is necessary to complete as soon as possible the emergency allocation project of ecological protection water resources in the east area of Yuxi city and the "three lakes" in the 12th five-year plan, unblock the 28km channel from Dalongtan of Panxi river to Qilu lake, lift 895m of water, replenish 50 million m³ of water annually in the near future, and transfer water from other watersheds to solve the problem of water shortage. Through the implementation of the ecological water supplement project in the outer basin, the benign flow field of Qilu Lake will be reconstructed, the power of Qilu Lake will be improved, the water circulation in the basin will be optimized, the water pollution purification capacity will be enhanced, and the water quality and aquatic animal and plant habitats of Qilu Lake will be improved. The water diversion project in central Yunnan has been started in its entirety. After completion in 2030, the ecological restoration water volume of Qilu Lake can be increased to 65 million m³/a. With the addition of water supply for industrial and agricultural life and production in this basin, the per capita water resource volume will be increased to 672m³/ person. The head lift of the first part of the project is 219m. It flows from the main canal He Guanying branch and enters Qilu Lake along Hongqi River.

According to the principle of "clear water entering the lake, recycling, comprehensive treatment and system allocation", the water resources system optimization simulation technologies [37] such as MIKE BASIN and ARC_WAS are adopted to reasonably allocate clean water and reclaimed water, local water and external water transfer, and carry out technical and economic analysis and calculation of water resources allocation. Taking the minimum cost of water supply as the goal and considering the constraints of life, production and ecological water supply guarantee rate, this paper studies and puts forward the basin water resources allocation and ecological dispatching scheme under the conditions of
clear water supplementing the lake, sewage interception and drainage, and quality-based water supply, so as to guide the water resources system planning and management practice of Qilu Lake basin.

Strict implementation of the "double control" of the national total water resources and consumption. On the basis of the fine allocation scheme of water resources in the basin, the annual total water consumption and monthly process of each field unit are approved. Water rights are distributed to each farmer, the encouragement and punishment system of "double control" of water resources and consumption is studied and promulgated. The predatory development of water and soil resources in Qilu Lake basin is curbed. Through satellite remote sensing and low-altitude unmanned aerial vehicle tilt photography and other three-dimensional and dynamic monitoring methods. The research strictly implements the crop rotation system formulated and released by the implementation plan of agricultural water saving and emission reduction, leaving time for arable land and water resources to recuperate. Through the remote control system, the water intake of each water intake facility (channel, pipeline, well, etc.) is automatically monitored and shut down due to excessive amount of water.

5. Conclusion
Qilu Lake Basin is one of the densely populated areas on the central Yunnan Plateau. Agricultural cultivation has a long history and the shortage of water resources can be traced back 400 years ago. Social progress, population increase and its demand for food have pushed the agricultural multiple cropping index to more than 300%. The predatory exploitation of water and soil resources in the basin has resulted in a large consumption of surface and groundwater resources, repeated reuse of lake water, non-point sources of farmland and decay of crop residues, which are the root causes of the deterioration of the lake water environment in Qilu. Many times of large-scale reclamation of lakes and extreme drought caused the water surface of lakes to shrink three times. After the "retreat of water and advance of human beings", the cultivated land in lakeside areas has been continuously expanded, but the vulnerability of lake water ecosystem has been aggravated. Under the historical opportunity of deepening reforms such as river length system, lake length system and ecological protection red line in the country, high and new technologies such as space-sky-ground three-dimensional monitoring system, ecological water-saving irrigation area and fine allocation of water resources are comprehensively applied, and water ecology is gradually restored, water environment is improved, water resources carrying capacity is increased, and a green beautiful countryside with clear water bank is built through the implementation of measures such as water saving and emission reduction in agriculture, reduction of agricultural multiple cropping index, delineation of ecological red line in river basin and control of water bank line, water supplement project in outer river basin, fine allocation of water resources and three-dimensional monitoring.

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