Investigation on Natural and Social Economic Situations and Pollution Status of Dianchi Lake Basin

Tiyuan Xia^{1, a}, Song Jin¹, Zuoxin Tang¹, Yuan Su², Zebin Chen^{1, 2, b, *}

¹College of Agronomy, Kunming University, Kunming, Yunnan Province, China.

²Key Laboratory of Characteristic Biological Resource Development and Utilization of Colleges and Universities in Yunnan Province, Kunming, Yunnan Province, China.

^axiatiyuan@sohu.com, ^bzbchenkmu@163.com

*Corresponding author: Zebin Chen

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Abstract: In the past 30 years, comprehensive treatment measures were used to control the pollution of Dianchi Lake basin. After the normal and abnormal periods, now the new normal period is coming, since the situations of agricultural production and agricultural non-point source pollution in Dianchi Lake basin have changed. How to prevent and control non-point source pollution better under the background of new normal has become a hot research issue. Based on statistical yearbooks of Kunming and field survey data from county areas, the research group carries out this study through conference discussion, data collection, field survey, data arrangement as well as data analysis and induction. Combined with the practice of pollution governance, the natural and social economic situations, as well as the pollution status of Dianchi Lake basin are analyzed. The aim of this paper is to provide a scientific basis for ecological restoration projects and land usage adjustment of this area, and provide theoretical support for the sustainable development of modern Kunming and the pollution control of Dianchi Lake basin.

1. Introduction

Dianchi is a famous plateau freshwater lake in China. It belongs to the Jinsha River system of Yangtze River basin. The beautiful Kunming City with an eternal spring is located on the bank of Dianchi Lake. The lake is called "the Pearl of Plateau" and the "Mother Lake" of Kunming. The area of Dianchi Lake is 300km2, which ranks sixth in inland lakes of China; its basin area is 2920km2; Dianchi is a closed and semi-enclosed lake [1-3]. Compared with plain lakes at home and abroad, Dianchi has typical characteristics of plateau lakes, such as short runoff source, accumulated water for many years, and long water replacement cycle. In 1970s, Dianchi had good water quality and biodiversity [4-6]. After 90s, eutrophication phenomenon occurred. Water in Dianchi became black and stinky; the water quality exceeded the standard of grade V. "Water bloom" appeared in large area and sustained for long time; fish and shrimp became fewer. In the Ninth Five Year Plan and 2010 Target Outline of National Economic and Social Development of People's Republic of China, Dianchi was listed as one of the three key lakes which needed to be controlled. [7] The existing investigation on the natural and social economic conditions, as well as the pollution status of Dianchi Lake basin is obsolete. Therefore, it is necessary to carry out a new round of investigation. Based on statistical yearbooks of Kunming and field survey data from county areas, the research group carries out this study through the forms of conference discussion, data collection, field survey, data arrangement as well as data analysis and induction. Combined with the practice of pollution governance, the natural and social economic situations, as well as the pollution status of Dianchi Lake basin are analyzed, in order to provide a scientific basis for ecological restoration projects and land usage adjustment of this area, and provide theoretical support for the sustainable development of modern Kunming and the pollution control of Dianchi Lake basin.

2. Natural Condition of Dianchi Lake Basin

2.1 Geography and hydrology

The Dianchi Lake basin is located in the Yunnan part of the Yunnan-Guizhou Plateau. Its geographical coordinates are 102°29'-103°01' east longitude and 24°29'-25°28' north latitude. It is located in the watershed of the Yangtze River, the Red River and the Pearl River, and belongs to the Jinsha River system; the area is shortage of water resource. [8,9] The basin area is 2920km2; it is long in north and south direction, and narrow in east and west direction. With Dianchi Lake as the center, a distinctive, asymmetrical geomorphic pattern of plateau basin is formed like a set of elliptical concentric circles with the increasing height of lake, lakeside plains and platforms in front of mountains. Among them, the area of Dianchi is 300km2, accounting for 10.3%; the area of lakeside plains is 522.8km2, accounting for 17.9%; the area of platforms in front of mountains is 945.6km2, accounting for 32.4%; the area of mountains is 1151.6km2, accounting for 39.4%. [10] Dianchi is constructed by tectonic fault. The lake is long and narrow and slightly arched. It covers 40.2km from north to south, and 12.5km from east to west. With 163km lakeshore line, Dianchi is the largest freshwater lake in Yunnan-Guizhou Plateau, and the sixth largest freshwater lake in the country. The waters of Dianchi are divided into two parts, Caohai and Waihai, which are separated by artificial gates. Waihai is the main body of Dianchi, and accounts for 96.7% of the whole lake. Caohai is located at the north of Waihai. There are 35 rivers flow into the lake. Most of them originate in mountain areas in the north, east and south of the basin. It has the characteristics of plateau lakes like short flow path of rivers flowing into the lake, and long replacement period of lake water. Rivers with large water volumes are Panlongjiang River, Baoxiang River, Xinyunliang River, Laoyunliang River, Chuanfang River and others. There are two manual controlled water gates, namely Haikou Middle Reaches Water Gate located at the west south part of Waihai, and Xiyuan Tunnel located at the west north part of Caohai. Through these two gates, water in Dianchi flows into Jinsha River through Mantis River and Padu River.

2.2 Climate

The Dianchi Like basin has a subtropical, semi-humid monsoon climate. The area is in low latitude and high altitude, and has low latitude plateau monsoon climate. Influenced by the lake effect of Dianchi and the protection of Wumeng Mountain, which can block cold air from the north, the area has large daily temperature difference and small yearly temperature difference. The dry and wet seasons are clear with warm, wet summer and cool, dry winter. The climate is pleasant. The annual average temperature is 14.7 degrees; the annual average rainfall is 953mm; the annual average evaporation is 1409mm; the annual sunshine duration is 2801-2970h; the annual average solar radiation is 5522J/m2 [11]. Main climatic disasters are drought, low temperature, flood and hail. Drought disasters occur frequently, almost every two years.

2.3 Vegetation

From the vegetation regionalization, eastern area of Dianchi basin belongs to humid forest area with subtropical evergreen broad-leaved forest belt; western area is the transitional zone of dry and wet, with evergreen oak forest in Yunnan plateau and pine forest in Yunnan province. [12] The main types of vegetation are warm evergreen broad-leaved forest, and mingled forest with subtropical warm coniferous forest. The subtropical warm evergreen broad-leaved forests are distributed in a vast range of area at the altitude of 1885-2500m. But only forests in Xishan Mountain, Bamboo Temple and remote mountain areas are well preserved. Due to human destruction, most of the original vegetation has been replaced by secondary vegetation. Most parts of the secondary vegetation are Yunnan pine forests located in the sunny slope of mountains; these forests are often mingled with oak forest of fagaceae. Seriously damaged areas even degrade into sparse forest grassland or shrub grassland. After many years of afforestation, the forest coverage in Dianchi basin has increased from 34.1% to 49%. The Dianchi Lake basin has a long history of farming, forming abundant farmland vegetation types. In the lake basin area of 1885-2000m height, multiple cropping methods are used;

farmers usually plant rice, broad beans, vegetables, and flowers. In hilly and mountainous regions with the height of 2000-2400m, aquatic and land plants are cultivated; early crops are the main species. Famers usually plant corn, potato and so on. In the mountainous basin with the height of 2400-2820m, coarse cereals are cultivated; farmers usually plant oats, buckwheat, other beans and vine. From 2008 to 2013, the "four retreats and three restorations" strategy, namely "to return the human used land, pond, field and house to lake, forest and wetlands" is carried out. 3600hm2 lake shore wetlands are constructed, including 667hm2 inner lake wetlands, 2467hm2 lakeside wetlands, and 467hm2 wetlands in front of mountains. [13]

2.4 Soil

The zonal soil in Dianchi basin is red soil. On the basis of that, the vertical distribution of brown soil, yellow brown soil and red soil is formed under the influence of climate and vegetation. The non zonal distribution of purple earth, atteration soil and boggy soil is formed under the influence of sedimentary basement; a large area of rice soil is formed after long-term artificial water culture. The distribution of soil types in Dianchi basin goes as following. Red soil is distributed in the vast area of Dianchi basin, accounting for 73.83%; rice soil is distributed in lakeside plains and platforms in front of mountains, accounting for 14.55%; purple soil is mainly distributed in Mesozoic strata located at the west of Padu River fault, accounting for 6.97%; brown soil is mainly distributed in lakeside plains, accounting for 1.43%; yellow brown soil is distributed in mountains areas and platforms in front of mountains, accounting for 1.28%; boggy soil is distributed in lakeside area, accounting for 0.31%.[14] With the rapid adjustment of agricultural structure, the soil types are changed. The area of rice soil decreases greatly and gradually becomes various vegetable soil; boggy soil is totally occupied (Table 1).

Table 1 Soil Types in Dianchi Lake Basin (km²)

Soil	red soil	rice soil	purple soil	brown soil	atteration	yellow brown soil	boggy soil	total
Area (km ²)	1544.91	304.51	145.82	34.07	30.01	26.85	6.44	2092.61
proportion (%)	73.83	14.55	6.97	1.63	1.43	1.28	0.31	100.00

Table 2. The administrative division of Dianchi Lake basin in 2015, including counties,	sub-districts
and towns.	

County	Towns and Urban Sub-districts						
Wuhua District	Huguo Sub-district, Huashan Sub-district, Daguan Sub-district, Longxiang Sub-district, Lotus Sub-district, Fengning Sub-district, Red Cloud Sub-district, Phuket Sub-district, Heilinpu Sub-district, Xizhu Sub-district						
Panlong District	Tuodong Sub-district, Gulou Sub-district, Donghua Sub-district, Union Sub-district, Jinchen Sub-district, Ciba Sub-district, Longquan Sub-district, Qingyun Sub-district, Shuanglong Sub-district, Songhua Sub-district, escrow Dianyuan Town and Ah Zi Ying Town of Songming County						
Guandu District	Wujing Sub-district, Taihe Sub-district, Guanshang Sub-district, Guandu Sub-district, Jinma Sub-district, Xiao Banqiao Sub-district, Da Banqiao Sub-district, Ala Sub-district, Yiliu Sub-district, Liujia Sub-district						
Xishan District	Majie Sub-district, Jinbi Sub-district, Yongchang Sub-district, Qianwei Sub-district, Fuhai Sub-district, Zongshuying Sub-district, Xiyuan Sub-district, Biji Town Sub-district, Haikou Sub-district, United Sub-district						
Chenggong County	Longcheng Sub-district, Dounan Sub-district, Wujiangying Sub-district, Luolong Sub-district, Yuhua Sub-district, Wulong Sub-district						
Jinning County	Kunyang Sub-district, Jincheng Sub-district, Shangsuan Town, Liujie Town						
Jingkai District	Escrow Yang Area of Chenggong District						
Resort District	Escrow Dayu Area of Chenggong District						
High tech District	Escrow Majinpu Area of Chenggong District						

3. Social and Economic Situations of Dianchi Lake Basin

3.1 Administrative division

The whole river basin of Dianchi is within the jurisdiction area of Kunming city. In 2000, the Dianchi basin covered 23 sub-districts of Wuhua District and Panlong District of Kunming, as well as 40 towns and sub-districts of Xishan District, Guandu District, Chenggong County, Jinning County and Congming County. The total number was 7 counties and districts, 63 towns and sub-districts. With the adjustment of administrative divisions in 2004, counties, villages and towns were merged and escrowed by urban districts. In 2015, the Dianchi Lake basin covered 54 sub-districts and 2 towns under the nine districts and counties of Kunming, including Wuhua District, Panlong District, Xishan District, Guandu District, Chenggong District, Jinning County, Jingkai District, Resort District and Hi-tech District. There were a total of 56 sub-districts. (Table 2)

3.2 Population

With the acceleration of urbanization in Dianchi basin, the permanent resident population and urban population have increased significantly since 2000, while the agricultural population has greatly reduced. By 2014, the total population increased from 2 million 486.1 thousand in 2000 to 3 million 968 thousand, with the increase amount of 1 million 481.9 thousand, total increase rate of 59.61% and average annual increase rate of 4.23%; the urban population increased from 1 million 715 thousand in 2000 to 3 million 552.3 thousand, with the increase amount of 1 million 837.3 thousand, total increase rate of 107.13%, and an average annual increase rate of 7.65%; the agricultural population dropped from 771.1 thousand in 2000 to 415.7 thousand, with the reduce amount of 355.4 thousand, with the total decrease rate of 46.09% and an average annual decrease rate of 3.29%. (Figure 1)



Figure. 1 Population in Dianchi Lake basin in 2000, 2005, 2010 and 2014

Note: The table is made according to data from Kunming statistical yearbook. For the data of 2000, the urban population is calculated according to population; the agricultural population is calculated according to agriculture. For the data of 2005 and 2010, the permanent resident population is calculated according to administrative division and meteorology; the agricultural population is calculated according to agriculture. The data of 2014 is calculated according to population. The data of the three villages in Songming were listed separately in 2000, and merged into Panlong District in the next few years. The data of areas escrowed by Jingkai, Resort and High tech districts are included in the data of original administrative divisions.

3.3 Land

The total land area of the Dianchi Lake basin was 2920km2. Using 3S to carry out Landsat TM/ETM + Photography of Dianchi basin, it is found in 2012, the cultivated land in Dianchi basin

was 739.10km2, accounting for 25.31%; forest land was 1259.07km2, accounting for 43.12%; grassland was 24.18km2, accounting for 0.83%; construction land was 574.71km2, accounting for 19.68%; water area was 322.95km2, accounting for 11.06%. (Figure 2) As it can be seen from Figure 2, from 2000 to 2005, cultivated land, forest and grassland decreased slightly, while construction land increased slightly; the urbanization of Kunming had not yet been accelerated. In 2003, the Meeting of City Construction Site of Yunnan Province was held in Kunming. Through more than two years' preparation and mobilization, the urbanization of Kunming began to accelerate and develop rapidly at the end of 2005. By 2012, the urban construction land increased from 276.97km2 to 574.41km2, the increase rate was more than 100%; the forest land was increased from 982.54km2 to 1259.07km2, increased by nearly 30%; cultivated land increased from 729.97km2 to 739.10km2, increased by only 1.25%; water area remained unchanged.



Figure 2. Land utilization in Dianchi Lake Basin

3.4 Economy

The Dianchi basin has a large population. With obvious regional advantages and rich natural, mineral, tourism and cultural resources, as well as excellent agricultural production conditions, it is the most potential area of Yunnan and the West China. As it can be seen from Figure 3, since 2000, the national economy has developed rapidly. The gross national product of the Dianchi Lake basin increased from 16 billion 681 million yuan in 2000 to 281 billion 692 million yuan in 2014, the increase rate was 1588.70%. The proportion of gross national product in Kunming was increased from 23.63% to 85.45%, which played a leading role in the rapid development of national economy in Kunming and Yunnan province.



Figure 3. Total gross national product of Dianchi Lake Basin and Kunming

4. The Pollution Status

There are 3 types of pollution sources in Dianchi basin, including point source pollution, non-point

source pollution and endogenous pollution. Point source pollution is divided into living source pollution, industrial pollution and third industry pollution. Non-point source pollution is divided into surface runoff pollution, atmospheric precipitation, dust pollution and agricultural source pollution. Endogenous pollution refers to the release of nutrients from lake sediments, mainly include nitrogen, phosphorus and heavy metal pollution released at the region of sediment-water interface. [15] In 2014, the input volume of point source pollution was 37907t. Compared with the 50631t in 2010, the reduce amount was 12724t, with the total decrease rate of 25.13%, and annual decrease rate of 5.03%. But the proportion of total amount of pollutants increased from 64.83% to 67.00%, with the increase rate of 2.17%. The input volume of non point source pollution was 18671t; in 2010 the number was 27459t. The reduce amount was 8788t, with the total decrease rate of 32%, and average annual decrease rate of 6.40%. But the proportion of total amount of pollutants reduced from 35.17% to 33%, with the decrease rate of 1.83% (Table 3).

The main pollutant guideposts of Dianchi Lake are CODcr, TN, TP, NH3-N and others. In 2014, the emission amounts of pollutants in Dianchi Lake were CODcr 143200t, TN 24300t, TP 2200t, NH3-N 14000t. Among them, the numbers of point source pollution volume were CODcr 107114t, TN 17885t, TP 1639t, NH3-N 12600t; the numbers of non-point source pollution volume were CODcr 36086t, TN 6415t, TP 227t, NH3-N 1400t. (table 4) The total emissions of point sources accounted for more than 70% of the total emissions; the highest proportion was up to 90%; point source pollution is the main source of pollution in Dianchi Lake basin.

pollution type	2010		2014		
	Total volume (t)	Proportion (%)	Total volume (t)	Proportion (%)	
point source pollution	50631	64.84	37907	67.00	
non-point source pollution	27459	35.17	18671	33.00	

Table 3 The volume and proportion of input non-point source pollution materials

	-			-	
pollution	Total volume (t)	point source	Proportion	Non-point source	Proportion
type		pollution (t)	(%)	pollution (t)	(%)
COD _{cr}	143200	107114	74.80	36086	25.20
TN	24300	17885	73.60	6415	26.40
TP	2200	1639	84.50	227	25.50
NH ₃ -N	14000	12600	90.00	1400	10.00

Table 4 The volume and proportion of pollution materials produced in Dianchi Lake basin

5. Conclusion

With the rapid development of Kunming City, the ecological and environment governance is also making progress; various pollutants are better controlled compared with earlier periods. The amounts of pollutants put into Dianchi Lake are significantly decreased with the construction of environmental protection facilities such as urban drainage system and sewage treatment system, the implement of comprehensive treatment and "four retreats and three restorations" policy, as well as the continuous promotion of various agricultural non-point source pollution control projects. At the same time, with the implementation of the third stage of sediment dredging project, the amounts of ammonia, dissolved orthophosphate, dissolved organic nitrogen and dissolved organic phosphorus are also reduced. These progresses alleviate the pressure of population and economic development on the environment and water quality of Dianchi Lake.

After 2000, the comprehensive management of Dianchi Lake basin has achieved initial success. The rapid social and economic development now exercises smaller influence on the water quality. The water quality deterioration trend of Waihai has been preliminarily controlled. The scientific and rational social and economic development model is of great significance to the protection of Dianchi. In order to further consolidate the results of Dianchi governance, following suggestions are proposed. First of all, decision-makers should come up with a clear city orientation strategy to determine the

appropriate scales of urban construction and population, and rationally adjust the industrial structure. Secondly, projects on the control of agricultural non-point source pollution should be promoted continuously to effectively reduce pollution while serving the local economic and social development. Finally, the area of ecological wetlands needs to be enlarged to purify the water quality, and make the self restoration capacity of ecosystem take effects. At the same time, more efforts and funds should be invested into the comprehensive management of Dianchi Lake. In order to achieve the coordinated and sustainable development of human and environment, supporting facilities like underground pipelines and sewage treatment facilities should be built.

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