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Comparison and Evaluation of Water Occupancy Rates of the Kılıçkaya Dam Lake (Turkey) between 2010-2021

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Abstract *— This study was carried out in Kılıçkaya Dam Lake in northeastern Turkey. Kılıçkaya Dam is a dam built between 1980-1989 to generate energy on Kelkit Stream. With this study, the water occupancy rates of Kılıçkaya Dam Lake, which has a proportionally large area, between the years 2010-2021 were compared and evaluated. If a general conclusion is drawn for Kılıçkaya Dam Lake, it has been determined that the water occupancy rates between the years 2010-2021 varied between 18.40 and 56.80 percent. The slope line of the water occupancy rates obtained in this study is downward. The results showed that the water occupancy rates in Kılıçkaya Dam Lake have a decreasing trend on an annual basis. When the average of the water occupancy rates between 2010-2021 is evaluated, the water occupancy rate values in Kılıçkaya Dam Lake indicate drought. The results obtained will be of great benefit to various users and decision makers in terms of their future planning within the framework of a comprehensive and large-scale drought management plan that is proposed to be prepared for the Kılıçkaya Dam Lake.*

Keywords *— **Drought, Kılıçkaya Dam Lake, Turkey.***

I. INTRODUCTION

Climate has direct and indirect effects on human life. The climate has been constantly changing over millions of years, and all living things are slowly trying to adapt to this changing climate. Some species have become extinct due to sudden changes in climate change in history. In the last century, climate change has been changing not by spreading over hundreds of years, but by decades. Noticing this change in the 1970s, human beings were worried about the future. Climate change causes changes in the proportions of the volumetric components of the atmosphere as a result of human activities and an increase in the greenhouse effect, which determines the temperature of the world. Some of the rays coming from the sun, which provides the heat energy of the world, are absorbed by the atmosphere, some remain on the earth and cause the greenhouse effect. Considering the characteristics of greenhouse gases, the greenhouse gas that has an important emission is carbon dioxide. While the largest share of total greenhouse gas emissions by activities is related to energy consumption, agricultural activities take the second place [1]. Human-induced increases in greenhouse gas emissions cause global warming and the climate changes accordingly. Climate change, which has been felt more in recent years, must be combated and urgent measures must be taken.

In Turkey, which is located in a semi-arid climate zone, drought events are frequently seen depending on atmospheric conditions, physical geography factors and climatic conditions. The sudden decrease

in precipitation that started in the Sahel Region of Africa and in the sub-tropical belt in the 1960s began to be effective in the Eastern Mediterranean Basin and Turkey (especially in winter) with the 1970s. Especially since the beginning of the 1970s, increases in the areal spread, frequency and severity of drought events have been observed in Turkey [2-7]. The fact that precipitation is below the long-term averages in many regions of Turkey has led to new meteorological drought events and subsequent agricultural, hydrological and socio-economic droughts. The most severe and widespread drought events in Turkey occurred in 1932, 1955-1956, 1971-1974, 1977, 1983-1984, 1989-1991, 1996, 1999-2001, 2007-2008 and 2013-2014 [7-10].

Dam lakes are artificial lakes built on streams for purposes such as electricity generation, drinking water supply, irrigation, fisheries, flood control, and recreation. Considering its wide variety of advantages, dam lakes have come to the forefront in terms of energy production compared to thermal and nuclear power plants, and due to the presence of stream sources, nearly 800 dams have been built in Turkey. Dam lakes are defined as "stream-lake hybrids" as they maintain the characteristics of the rivers on which they are built, and at the same time, they are structures that have the characteristics of the stagnant water mass formed. The wider the catchment basins, the more they are affected by pollution and climate change in the basin [11]. In recent years, the protection and monitoring of water resources is one of the most important issues for states.

There are 861 dam lakes in operation in Turkey. The climate of Turkey is semi-arid. Due to the fact that Turkey is surrounded by seas on three sides, high mountain ranges stretch along the coasts, the elevation increases from west to east, and the distance to the coast, temperature, precipitation and winds in Turkey vary according to the region and time. Turkey's long-term precipitation average is 574 mm annually, corresponding to an average of 450 billion cubic meters of water per year. The Eastern Black Sea Region is the place with the highest rainfall (1200-2500 mm/year). On the other hand, the Central Anatolia Region is the place that receives the least rainfall (250-300 mm/year). Apart from the coastal settlements of the Mediterranean and Southern Aegean Regions of Turkey, snowfall is observed in the winter months. Within the framework of today's technical and economic conditions, the surface water potential that can be consumed for various purposes is an average of 94 billion cubic meters per year. Together with the groundwater potential determined as 18 billion cubic meters, the consumable surface and underground water potential of Turkey is 112 billion cubic meters per year, 57 billion cubic meters of which is used. The annual amount of usable water per capita in Turkey was 1652 cubic meters in 2000, 1544 cubic meters in 2009, and 1346 cubic meters in 2020. Considering the usable water potential per capita, Turkey is among the countries experiencing water pressure [12]. For these reasons, it is of great importance to use water economically and optimally.

Kılıçkaya Dam Lake Basin, located in the Yeşilırmak River Basin, has a catchment area of approximately 8146 square kilometers. Kılıçkaya Dam Lake Basin, which has a very rough terrain, is located on the mountains extending in the east-west direction and on the fragmented depression areas with faults in the south of the Eastern Black Sea Mountains. Kılıçkaya Dam Lake Basin has a completely mountainous and rough terrain and is surrounded by mountains. In addition, elevation differences in the basin vary in short distances. In the Kılıçkaya Dam Lake Basin, although the temperature has decreased as a result of the increase in continentality compared to the Black Sea coast, a fully continental climate is not experienced. Precipitation shifts to spring and summer drought becomes evident. In addition, the number of snowfall and snow-covered days' increases in the winter season. A transitional climate from the Eastern Black Sea climate to the continental climate is dominant in the Kılıçkaya Dam Lake Basin. For this reason, summer months are generally hot and dry, and winter and spring months are rainy [7, 13]. According to Katipoglu et al. [14], it has been determined that increasing hydrological drought trends are dominant in the Yeşilırmak River Basin, where Kılıçkaya Dam Lake is located, in monthly and annual time periods.

With the completion of the construction of Kılıçkaya Dam Lake in 1989, the potential of Kelkit Stream was evaluated and it was possible to use it for multiple purposes. In this study, the water occupancy rates of the Kılıçkaya Dam Lake, which has a proportionally

large area, between the years 2010-2021 were examined.

II. MATERIALS AND METHODS

Kılıçkaya Dam Lake, chosen as the research area, is located on the 320 kilometers long Kelkit Stream, which is one of the important branches of the Yeşilırmak River. Kılıçkaya Dam is located about 130 kilometers from Sivas city center. Kılıçkaya Dam Lake is located 25 kilometers from the town of Suşehri. The district is located at the intersection of 38^0 05' 45" East longitude and 40^0 09' 45" North latitude. Some technical specifications of Kılıçkaya Dam Lake are presented in Table 1. Kılıçkaya Dam is located on the Kelkit Stream in the Türkmenler village of the Suşehri district of Sivas province. Kılıçkaya Dam construction was completed on November 15, 1989. The height of the dam built with rock filling type is 134 meters from the river bed. At the normal water level of Kılıçkaya Dam, the lake volume and lake area are 1400390000 m^3 and 64.42 km^2, respectively. The maximum depth of the Kılıçkaya Dam Lake is around 100 meters. Kılıçkaya Hydroelectric Power Plant produces 332 GWh of energy per year with 124 MW of power [15]. According to the monthly average temperature data obtained from the State Meteorology Directorate in Turkey, the annual average temperature in the Kılıçkaya Dam Lake Basin is 10 ^oC. The hottest months are July and August, and the coldest months are January and February. Total annual precipitation in the Kılıçkaya Dam Lake Basin also differs from year to year. Considering the entire Kılıçkaya Dam Lake Basin, the annual average precipitation is around 489 mm. This amount corresponds to a value below the annual average precipitation amount in Turkey. According to the precipitation data of long years, the highest precipitation in the basin is observed in April and May in the spring season, and the least precipitation is observed in July and August in the summer season. It has been observed that the rainiest season after the spring season is the winter season. The monthly average inflow to Kılıçkaya Dam Lake is approximately 61.16 m^3/second, the maximum monthly average inflow amount is 358.56 m^3/second and the minimum monthly average inflow amount is 1.8 m^3/second [7].

Table 1: Some technical specifications of the Kılıçkaya Dam Lake.

Technicial Specifications	***Kılıçkaya Dam Lake***
Date of Construction Start	13.11.1980
Date of Construction End	15.11.1989
Purpose of the Dam	Energy
Stream	Kelkit Stream
Body Fill Type	Rock
Height	134.00 m
Lake Volume	1400.39 hm^3
Lake Area	64.42 km^2

In this study, the values of the water occupancy rate data between 2010 and 2021 for the Kılıçkaya Dam Lake belonging to the General Directorate of State Hydraulic Works in Turkey were used. The occupancy rate calculations were determined according to the ratio of the active dam volume to the total dam volume. The occupancy rate values of Kılıçkaya Dam Lake are expressed as a percentage (%).

III. RESULTS AND DISCUSSION

Changes in the annual average water occupancy rates of Kılıçkaya Dam Lake between 2010 and 2021 are presented in Figure 1. When the water occupancy rates of Kılıçkaya Dam Lake are compared, a fluctuation trend has been observed from 2010 to 2021. The water occupancy rate for 2010 was determined as 22.72 percent. In 2011, 2012 and 2 013, the water occupancy rate increased to 32.27, 49.10 and 53.90 percent, respectively. In 2014, the water occupancy rate decreased to 29.50 percent. In 2015 and 2016, the water occupancy rate increased again to 54.00 percent and 56.80 percent, respectively. In 2017, 2018 and 2019, the water occupancy rate decreased again to 48.80, 40.80 and 24.20 percent, respectively. In 2020, the water occupancy rate increased to 35.80 percent. In 2021, the water occupancy rate decreased to 18.40 percent (Figure 1). The highest occupancy rate level was found to be 56.80 percent in 2016 and the lowest occupancy rate

level in 2021 was 18.40 percent for Kılıçkaya Dam Lake. The average of the annual water occupancy rates of the Kılıçkaya Dam Lake for the period between 2010-2021 was calculated as percent 38.86 and its standard deviation as ±13.55. These figures indicate that approximately 60 percent of the Kılıçkaya Dam Lake was empty in the 2010-2021 period, that is, it was not filled. Accordingly, it is seen that the water occupancy rates of Kılıçkaya Dam Lake are at low levels. The slope line given in Figure 1 also confirms this decrease. This indicates that the water level in Kılıçkaya Dam Lake decreased significantly in the 2010-2021 period due to the effect of drought.

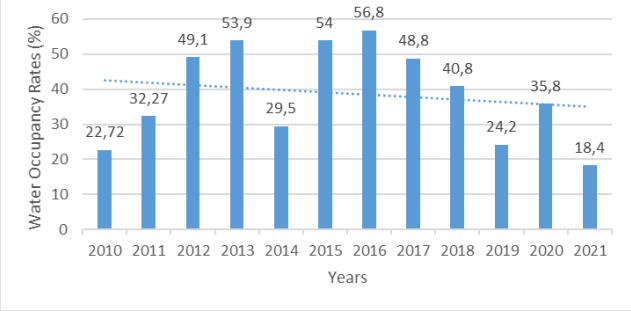

Fig. 1: Change in water occupancy rates of Kılıçkaya Dam Lake between 2010-2021.

In the studies carried out in Çermikler, Gazibey, Gölova, Maksutlu ve Karacalar dam lakes in Sivas province, a downtrend was detected in water occupancy rates similar to Kılıçkaya Dam Lake [16-20].

Kılıçkaya Dam Lake has first class water quality and its annual average nitrate value varies between 1.9-2.8 mg/L [21]. According to TWPCR [22], the water of Kılıçkaya Dam Lake, which has first class water quality, can be disinfected and used not only for drinking purposes, but also for recreational purposes, rainbow trout farming, animal production and other purposes. For these reasons, Kılıçkaya Dam Lake is an important water source for Turkey and its region.

With the effect of drought and lack of precipitation, significant recessions in water level are observed in Kılıçkaya Dam Lake with the decrease in water occupancy rates. In 2021, the lowest water occupancy rate was determined as 18.40 from Kılıçkaya Dam Lake (Figure 1). In the Kılıçkaya Dam Lake, which is located in the Suşehri district of Sivas province, drought was observed in the summer months of 2021, which occurred with the withdrawal of water. It has been observed that only the bed of the Kelkit Stream, which forms and feeds the dam, remains from the Kılıçkaya Dam Lake, which once resembled the sea. It is predicted that the decrease in precipitation caused by climate change and the increase in temperatures will increase the evaporation effect, severity and duration of Kılıçkaya Dam Lake, and accordingly, the decrease in water occupancy rates will be more in the future.

The fact that the precipitation in Turkey was below normal in all regions in 2021 caused the hydrological drought effect and a decrease in the share of hydroelectric energy production in total electricity production. Hydroelectric energy production, which was 88,879 GWh in 2019, decreased by 12.5% to 78,095 GWh in 2020. This decline continued in 2021 as well. In the first 5 months of 2021 in Turkey, there have been dramatic decreases in the amount of water coming to hydroelectric power plants, which are water-dependent electricity generation sources, compared to the long-term average. As the amount of water coming to the main watershed dams generating electricity in Turkey remained below the long-term average of 66 percent in the first 5 months of 2021, its share in electricity generation decreased from 31 percent to 23 percent as of May 2021. Similarly, while 49.1 billion cubic meters of water came to the dams on average in the first 5 months, the water remained at 24.3 billion cubic meters in the first 5 months of 2021. In short, the water coming to the energy-producing dams in the first 5 months was not even half of the average incoming water for many years in 2021. The incoming water in May 2021 is 54.1 percent less than the incoming water in the same month of 2020; As of the end of May 2021, the water incoming in the 5-month period was 38.9 percent less than the water incoming in the same period of 2020 [23]. The flow rate in all of the rivers in Turkey has decreased between 20 and 70 percent. Kelkit Stream feeding the Kılıçkaya Dam Lake has also taken its share from this situation.

The decrease in the water coming to the hydroelectric power plants seems to disrupt the electricity production balance. As of April 2021, the first 3 sources in the electricity generation of licensed power plants are hydroelectric energy with 31.10 percent;

While coal with 28.48 percent and natural gas with 21.59 percent, there were drastic changes in these rates in May. In May, the first 3 sources in electricity generation by licensed power plants are coal with 29.70 percent; natural gas with 27.62 percent; Hydroelectric energy was 23.25 percent. In years with normal or abundant water income, the share of hydroelectric power plants in electricity generation would reach 40-45 percent, especially in spring. However, in May 2021, the share of hydroelectric power plants remained below 25 percent [23]. Accordingly, the drought has also negatively affected the electricity production of Kılıçkaya Dam Lake. Despite the decrease in the water in the dams, especially in the spring and summer months, Turkey needs to increase the share of renewable resources such as solar and wind, which are domestic sustainable resources, in the portfolio in order to compensate for the increased electricity consumption. Hydroelectric power plants should be supported in the dry years like 2021. Against the risk of the drought continuing in the coming years, resource planning should be done in energy. For this reason, it would be very beneficial for energy management to make a production and energy supply planning that takes into account possible hydrological drought, as well as water management.

The drought, which has taken the world and Turkey under its influence, also shows itself in Kılıçkaya Dam Lake. Long-term droughts were observed in the Kılıçkaya Dam Lake Basin in 1954-1959, 1969-1970, 1972-1975, 1989-1990, 1993-1994, 2000-2002, 2007-2008 and 2012-2013 periods [7]. According to Katipoğlu et al. [14] determined as a result of trend analysis that droughts tend to increase in the Yeşilırmak River Basin, where Kılıçkaya Dam Lake is located. However, the drought, which started with the decrease in precipitation and climate changes, has been increasing day by day in recent years and is progressing in Kılıçkaya Dam Lake. Global climate change and drought caused by the decrease in precipitation cause significant decreases in water level in Kılıçkaya Dam Lake. As a result of the global climate change, which has been more effective since 2016, and the drought caused by the decrease in precipitation in Kılıçkaya Dam Lake, the water level continues to decrease in the Kelkit Stream feeding the Kılıçkaya Dam Lake and in the creeks. After 2016, the water level in Kılıçkaya Dam Lake has been decreasing every year (Figure 1). Kelkit Stream has shrunk due to drought. Due to the decrease in water levels in Kılıçkaya Dam Lake, especially fishermen have suffered a lot in recent years. With the marked decrease in the water occupancy rates of Kılıçkaya Dam Lake in recent years, many areas, especially fisheries and energy, are adversely affected.

IV. CONCLUSION

While 2016 was the year with the highest occupancy rate in Kılıçkaya Dam Lake, the year with the lowest occupancy rate was found in 2021. If a general conclusion is drawn for Kılıçkaya Dam Lake, it has been observed that the water occupancy rates varied between 18.40 and 56.80 percent between 2010-2021. The data show that there are extreme decreases in water occupancy rates in Kılıçkaya Dam Lake. The results support that, as a result of the decrease in precipitation due to global climate change, the decreases in the water occupancy rates of Kılıçkaya Dam Lake will be greater with the future occurrence and severity of drought. All these show that the effects of drought in Kılıçkaya Dam Lake may be felt even more in the future. According to the results obtained, it is recommended to create a comprehensive and large-scale drought management plan for Kılıçkaya Dam Lake. Accordingly, drought risks should be managed and measures to be taken against drought should be implemented in an integrated manner in Kılıçkaya Dam Lake.

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