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# The Effect of Climate Change on Hydroelectric Energy Production in the Upper Euphrates Basin: A Review

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**Abstract:- Türkiye, the upper riparian country of the Euphrates River Basin contributes 89 % to the flow of the Euphrates River flow [23]. Especially in the Turkish part of the Euphrates River Basin, it is estimated that precipitation and snowfall in the basin will decrease by 30–40% by the end of the century** [24].

**Keban, Karakaya, and Atatürk Dams are located in line with the Euphrates River and still generate about 12% of the total amount of hydroelectric energy of Türkiye. Keban Dam is the most upstream dam among them.The water released from the Keban Dam is used by other dams to generate hydroelectric energy in a synchronized manner.**

**All of these dams have started to generate energy together since 1993. This study aims to investigate the causes of decreasing annual energy generation from all three dams between 1993 and 2022. In this study, we have noticed that the total electricity generated from these three dams has started to gradually decrease since 1998. In the last five years, it has been determined that this energy has decreased by one-quarter compared to the start of generation. In the study, the reasons for this decrease were investigated, and the results obtained were presented.**

**As a result, the total electricity generation from Keban, Karakaya, and Atatürk Dams has gradually decreased by 25% in the last 30 years compared to the energy generation starting in the early 1990s. The decrease in the hydroelectric energy will have economic consequences in Türkiye as well as will affect the water management and hydropolitics of the region. We obtained that the decline in electrical energy generation is in great correlation with the droughts in the region. This shows that a decrease in rainfall and snowfall has led to a decrease in the average annual flow of the Euphrates River in the last 30 years.**

**This result is also compatible with the results of many scientific studies on climate change effects in the Euphrates and Tigris River Basin and analyses of the average annual snowfall measurements in the Upper Euphrates River basin. We hope that this study will be beneficial to raising regional awareness about climate change effects in regional hydropolitics as well as climate change adaptation measures to be taken.**

***Keywords:-*** *Climate Change,Euphrates River Basin, Hydroelectric Energy, Transboundary River,Water-Energy Nexus,Water Management .*

## I. INTRODUCTION

Hydroelectric energy, as a domestic and renewable energy source, has an important place in Türkiye's energy generation in economic and strategic terms. In 2022, 20% of electrical energy generation was provided by hydroelectric energy in Türkiye. In 2022, the total hydroelectric energy generation in Türkiye was 67195.4 GWh. 17.5% of this generation which is 11784.5 Gwh, was generated in Keban, Karakaya and Atatürk Dams.[5]

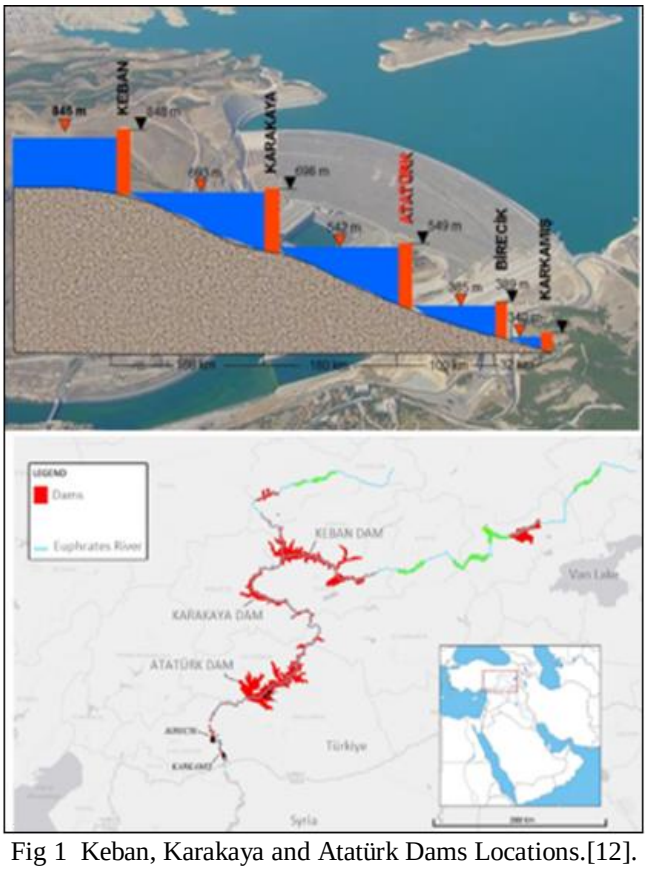

Fig 1 Keban, Karakaya and Atatürk Dams Locations.[12].

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These dams started to generate hydroelectric energy synchronously with the commissioning of the Atatürk Dam in 1993. In the five years following 1993, this generation was at its highest level in the last 30 years and then started to decrease gradually. From 1993 to 2022, the total annual energy generation of these dams fell below the project generation at various rates 17 times. Among these dams, the one with the highest gradual decrease in annual energy generation was the Atatürk Dam. In the Atatürk Dam, it was 45% below the annual project generation capacity of 8.9 Gwh in nine years of the last 30 years. In summary, there has been a clear, gradual, decreasing trend in the annual energy generation of Keban, Karakaya, and Atatürk Dams for the last 30 years. In this study, the reasons for this decrease were investigated.

Table 1 Keban, Karakaya,Karakaya and Atatürk Dams Characteristics [11].

| Dams | Completion Date | Installed Capacity (MW) | Dam Height (m) | Reservoir Volume ($hm^3$) | Reservoir Surface Area ($km^2$) |
|---|---|---|---|---|---|
| Atatürk Dam | 1992 | 2400 | 169 | 48.700 | 817 |
| Karakaya Dam | 1987 | 1800 | 173 | 9.580 | 268 |
| Keban Dam | 1974 | 1330 | 210 | 31.000 | 675 |

➢ *Keban ,Karakaya and Atatürk Dams Characteristics:-*

Among these dams, Keban Dam is the first dam built on the Euphrates River. It was completed in 1974 to generate 6.6 billion kWh of electrical energy annually with an installed power of 1330 MW. Karakaya Dam was completed in 1987 and can generate 7.5 billion kWh of electrical energy annually with an installed capacity of 1800 MW. Atatürk Dam has an annual electrical energy generation capacity of 8.9 billion kWh with an installed capacity of 2400 MW (Table 1).

As can be seen from Table 1, Keban Dam was put into operation in 1974, Karakaya Dam in 1987, and Atatürk Dam in 1992. The operating programs of these three dams have been planned synchronously with each other since 1992, and energy generation has started.

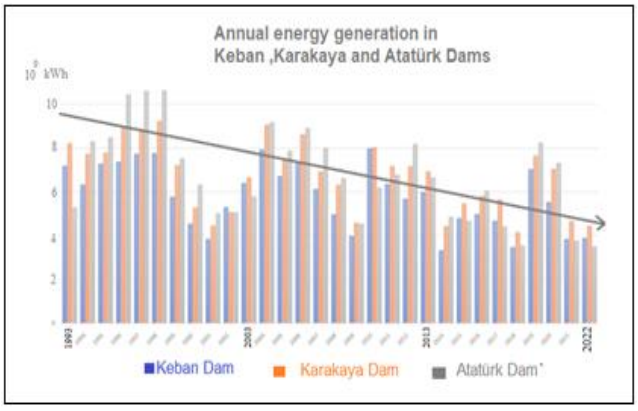


Fig 2 Change of electrical energy generated from Keban, Karakaya, and Atatürk Dams over the years

## II. ENERGY GENERATION IN KEBAN, KARAKAYA AND ATATÜRK DAMS

In this study, the year 1993 was taken as the starting point because the energy generation of Keban Karakaya and Atatürk Dams started to generate electrical energy in conjunction with each other. The amounts of annual energy produced by these dams between 1993 and 2022 are given in Fig.1. The annually produced electrical energy data used in creating these graphs was obtained from the web page www.enerjiatlasi.com/hydroelektrik. Fig.2 shows that there has been a decreasing trend in the annual amount of electrical energy generated from Keban, Karakaya and Atatürk Dams in the last 30 years.

## III. EVALUATION OF ENERGY GENERATION IN YEARS

When evaluating the electrical energy generation from Keban, Karakaya and Atatürk dams, it should be taken into consideration that Keban Dam is a dam at the very upstream point. For this reason, the flow released from the Keban dam first enters the Karakaya Dam reservoir, and its energy is taken and reaches the Atatürk Dam reservoir. In other words, when an efficient operating program is implemented, twice as much energy is produced with the flow released from the Keban dam. The installed power plant capacity of Keban Dam is 1330 MW, of Karakaya Dam is 1800 MW, and of Atatürk Dam is 2400 MW. In this case, looking at the installed power plant capacities of the dams, it can be thought that, with a general evaluation, the annual electrical energy produced from Keban Dam will be less than that produced from Karakaya Dam, and the annual electrical energy produced from Karakaya Dam will be less than that from Atatürk Dam. When Fig.5 is examined, it is seen that electricity generation amounts were realized in accordance with this evaluation in 18 of the last 30 years. In these 18 years, energy generation amounts were realized as the generation from Atatürk, Karakaya and Keban Dams, from the largest to the smallest of the installed power plant capacities. In the other 12 years, the electricity generation at Atatürk Dam was generally lower than that of Karakaya Dam.

➢ *Electrical energy generation amounts in the 10-year period between 1993 and 2022:-*

There is a gradual decrease in the total electrical energy generation of Keban, Karakaya and Atatürk Dams in 10-year periods.

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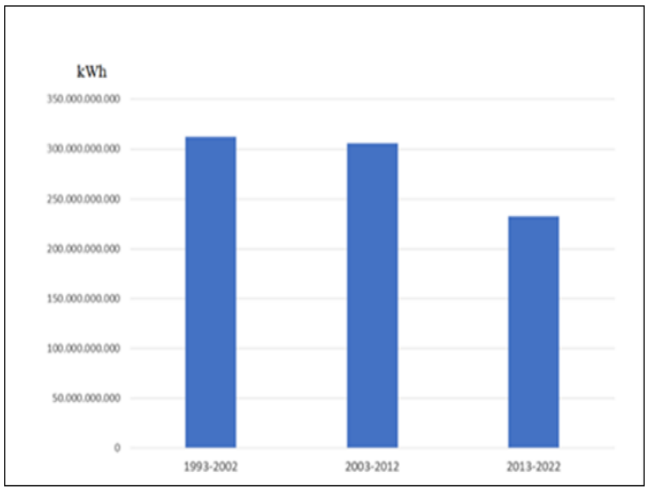


Fig 3 Change of Total Electrical Energy Generation in Keban, Karakaya and Atatürk Dams According to 10-Year Periods

In the 30-year period between 1993 and 2022, the total electrical energy produced in Keban, Karakaya and Atatürk Dams in 10-year periods was as follows: 1st Period: 1993-2002: 312,346,481,000 kWh; 2nd Period: 2003-2012: 305,658,020,000 kWh; 3rd Term: 2013-2022: 232,795,243,460 kWh. The change in the total electrical energy produced from Keban, Karakaya and Atatürk dams in 10-year periods in the last 30 years is given in Fig.2. While 312.3 billion kWh of energy was generated from these three dams in the first decade (1993–2002), this value increased to 305.6 billion kWh in the second decade (2003–2012) and 232.8 billion kWh in the third decade (2013–2022). There has been a decreasing trend in the electrical energy generated from all three dams in the last 30 years (Fig.1). The most dramatic decrease occurs at the Atatürk Dam.

It is also seen that the electrical energy generated has decreased dramatically in the last three decades since 1993, when all three dams began to be operated synchronously. The total electrical energy produced from these three dams in the first decade has decreased by 24% in the last decade. Considering the year scale, energy generation has decreased to 55% in the last few years compared to the years in the first period starting in 1993. In other words, the electrical energy produced from these three dams has gradually decreased in the last 30 years. This decrease has reached up to 55% in the last two years, compared to the early 1990s.

## IV. EXAMINING THE REASONS FOR THE DECREASE IN ENERGY GENERATION

➢ *These reasons will be examined by taking into account the four main issues given below:-*

- The decrease in precipitation falling on the Keban Dam watershed over the years, and mainly the decrease in the water entering the Keban Dam reservoir
- Failure to implement an operating program to maximize energy generation in Keban, Karakaya and Atatürk Dams
- The increase in irrigation dams and irrigation projects in the Upper Euphrates and Middle Euphrates river basins that feed the Keban Dam and the decrease in the amount of water reaching the Keban Dam reservoir
- Reducing energy generation due to the increase in the amount of water drawn from the Atatürk Dam lake for irrigation. For the reasons mentioned above, it is unlikely that there will be a decrease in energy generation because an optimal dam operating and energy-generating program cannot be implemented for many years.
- In addition, if we think that the decrease in energy generation due to the increase in the amount of water drawn from the Atatürk Dam reservoir for irrigation, this could should only be effective in electricity generation in the Atatürk Dam, But we see that the decrease in electricity generation occurred synchronously and in harmony with each other in the three dams. This reveals that the reason that reduces electricity generation has an integrated effect on all dams.

➢ *Increase in irrigation dams and irrigation projects in the Upper Euphrates and Middle Euphrates river basins that feed the Keban Dam:-*

The consequences of the increase in irrigation dams and irrigation projects in the Upper Euphrates and Middle Euphrates basins that feed the watershed of the Keban Dam reservoir are examined in detail below.

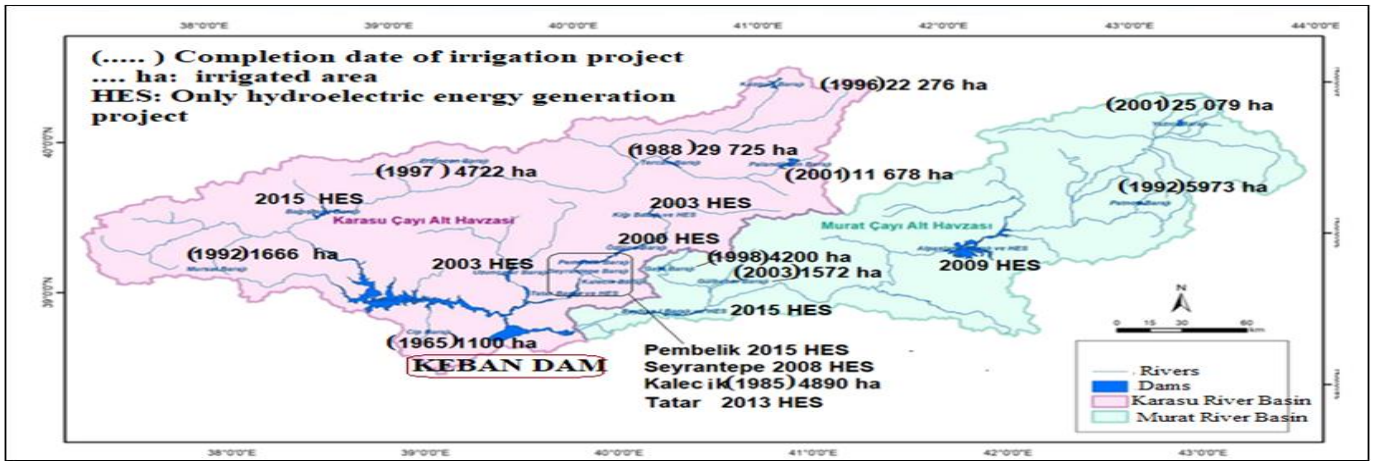


Fig 4 Irrigation Dams and HEPP Projects were Built on Various Dates in the Watershed of Keban Dam[1].

When Fig.4 is examined, it can be seen that seven irrigation dams with 75,500 hectares irrigation land were put into operation after the year 1993 in the Keban Dam watershed. In this case, if the amount of water withdrawn per hectare per year is taken as 10 000 $m^3$, it turns out that a total of 755 million $m^3$ of water is directed to irrigation before reaching the Keban dam. This means that the amount of water arriving at Keban Dam annually, which is 21 billion $m^3$, will decrease by only 3.5% (Fig. 5).

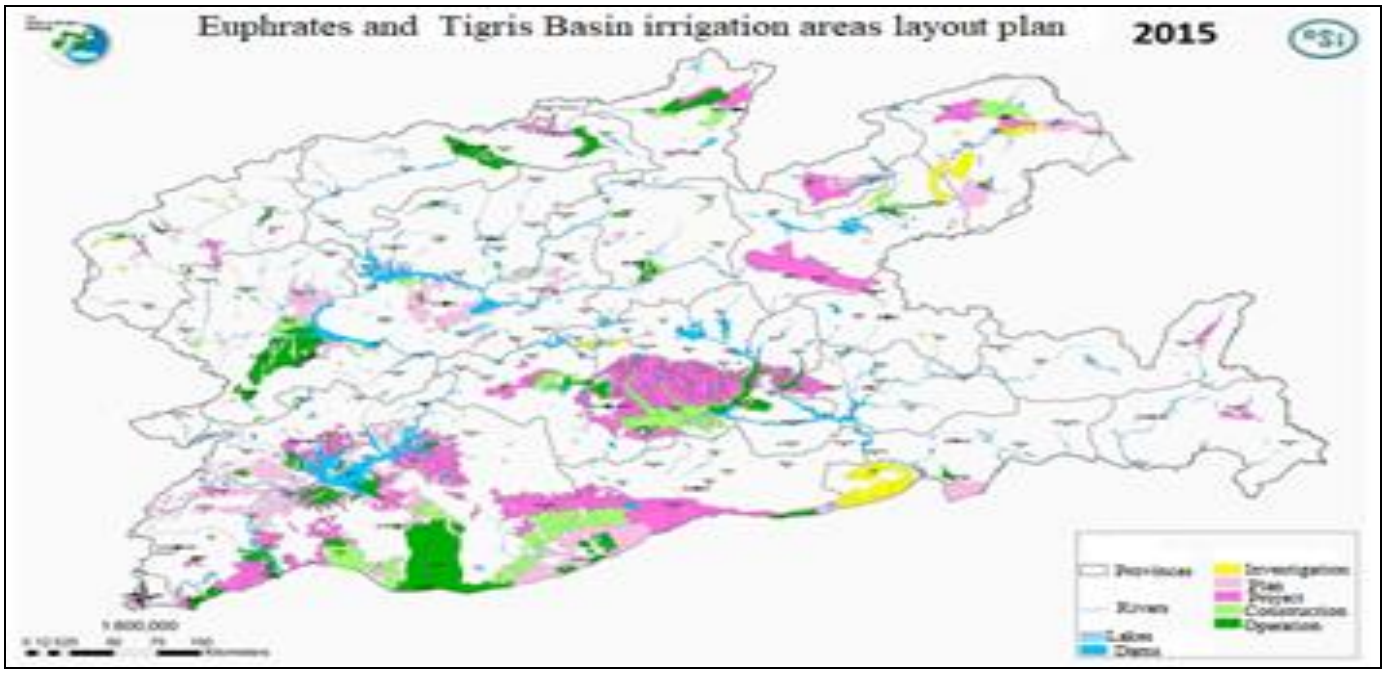


Fig 5 Euphrates and Tigris Basin Irrigation area Layout Plan [6].

It is thought that a 3.5% decrease in the total amount of water coming to the Keban Dam's watershed annually due to the lands developed for irrigation hasn't been a major impact on this decrease in energy generation over the years.

- *80% of the water used for total hydroelectric energy generation in the Euphrates River comes from the Keban Dam watershed. :-*

The Euphrates River, which has the largest basin in Turkey, carries an average of 30 billion $m^3$ of water within Turkey annually. 80% of this water originates from the Keban Dam watershed. The average flow rate at the Keban Dam site is around 700 $m^3/s$. This flow rate increases rapidly in spring due to rain and snowmelt, reaching up to 2000 $m^3/sec$. Discharge begins to decrease starting in July and reaches its lowest level in September–October. After the Keban Dam, a total annual discharge of approximately 4-5 billion $m^3$ comes from the lower basin that feeds the Karakaya and Atatürk Dam reservoirs. In this case, the decisive basin in the energy generation potential of the Euphrates River is the Keban Dam basin. Karakaya and Atatürk Dam reservoirs are fed mostly by the turbined flows released from Keban HEPP for energy generation and by small amounts of water coming from the lower basin between the two dams.


Fig 6 The Keban, Karakaya and Atatürk Dams' watersheds area in the Eastern Anatolia Region [11].

➢ *Annual Precipitation in the Keban Dam Watershed:-*

When Fig.6 is examined, it is seen that the Upper Euphrates and Middle Euphrates watershed which feed the Keban and Karakaya Dams' reservoirs, remain within the borders of the Eastern Anatolia geographical region. Although this does not exactly represent exact Keban Dam's watershed borders, it gives general information about the annual areal rainfall values that could feed to Keban and Karakaya Dams' reservoirs in the region.

It is seen that annual areal precipitation in the Eastern Anatolia region has been in a decreasing trend since the 1990s and has been well below the average in many years since 2008. This decrease has been eventually effective to decrease the flows to the Keban and Karakaya Dams reservoirs.

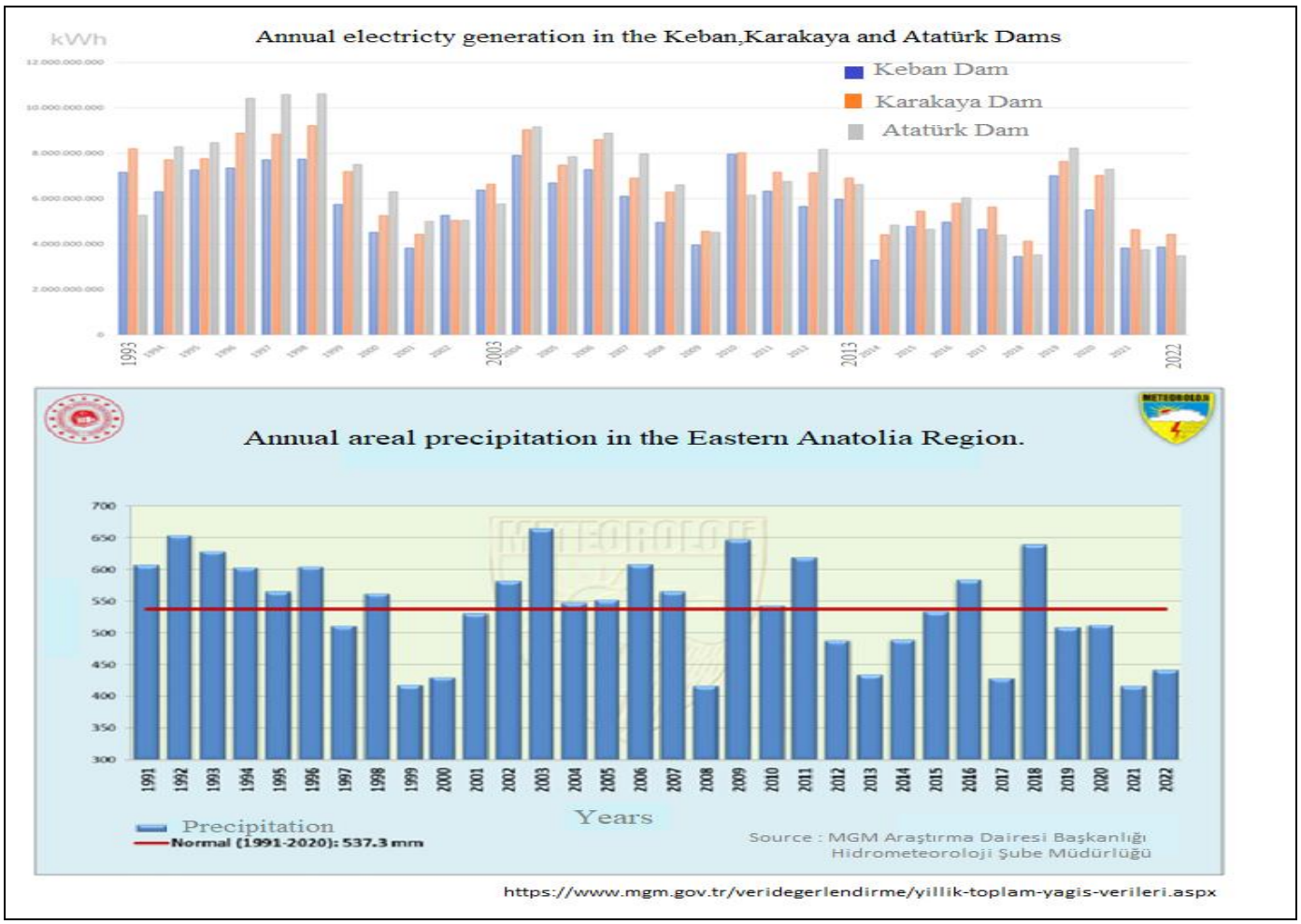


Fig 7 Total annual energy generation in Keban, Karakaya and Atatürk Dams and annual areal precipitation in the Eastern Anatolia Region. [3]

The Keban Dam watershed lies in a large part of the Eastern Anatolia region. When Fig.6 is examined, it is seen that the change in annual areal precipitation in the Eastern Anatolia region is effective on the annual amount of electrical energy generated from Keban, Karakaya and Atatürk Dams one year later (Fig.7).

The reason for this is that Keban and Atatürk Dam reservoirs, except the Karakaya Dam reservoir, have very large volumes (Table 1). The normal operating reservoir water level at Atatürk Dam is 532 m. At this water level, approximately 720 million $m^3$ of water must enter the reservoir to rise it only 1 m. For this reason in these dams , increases and decreases in reservoir water levels occur between only 3-5 m during dry and rainy periods. This extreemly high voume of reservoirs bring an opportunity to consider incoming waters for the next year's electrical energy generation planning. Therefore, except for very unusually rainy or extreemly drought years, amount of incoming watres generally have an impact on the next year's electrical energy generation (Fig.7).

Another reason for this one-year delay effect in electricty generation is that the electricty generation operation of these three dams is carried out synchronously with each other. Therefore electricty generation plan hasn't been revised immidietly when increase or decrease in the amount of precipitation occurs in the Keban Dam watershed.

Therefore it doesn't immediately turn into an increase or decrease in electrical energy generation due to synchronizing the energy generation of the three dams.

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As shown in Fig.7, the lowest areal precipitation of the last 20 years in the Eastern Anatolia Region fell in the years 1999, 2000, 2008, 2013, 2017, and 2021.

This didn't lead to a decrease in the electrical energy generated in the same years. But the years 2000, 2001, 2009, 2014, 2018, and 2022. The Eastern Anatolia Region received much above-average precipitation in 1996, 2003, 2009, and 2018, and these rainfalls were accumulated in the reservoirs of Keban, Karakaya, and Atatürk Dam. This effect appeared as an increase in electrical energy generation in 1997, 2004, 2010, and 2019. Because the Keban Dam watershed is mostly fed by snowmelt, it takes until the middle of the year.

Secondly, since the reservoir volumes of the Keban and Atatürk Dams are very large, the inflow is retained in these reservoirs and benefits the next year's energy generation. Again, in years when rainfall was low, the effect of this on the decrease in energy generation occurred with a one-year delay. As explained before, the reason for this is that the dam's reservoir volume is very large and the decrease in precipitation is reflected in the lake water level towards the middle of the year, and this decrease effect is taken into account in the next year's electrical energy generation operation program.

The reason why the energy produced increases and decreases at the same rate in all dams can be explained as Karakaya and Atatürk dams also generate electrical energy from the water released from Keban HEPP. The reason of higher energy generation in Karakaya and Atatürk HEPP may be due to the difference in the specific flow rates used in energy generation and the flow rate entering the Atatürk Dam from the lower watershed.

➢ *The decrease in snowfall in the Euphrates River basin*

General Directorate of Meteorology (MGM) investigated whether there was any change in the amount of snowfall in the basin with the construction of dams in the Euphrates river basin. Mann-Kendall Correlation Coefficient (Trend Analysis) was performed and long-term data of Gaziantep, Şanlıurfa, Adıyaman, Malatya, Elazığ and Tunceli meteorological stations close to the Euphrates river basin were examined.

An attempt was made to reach a conclusion by comparing the observations and comparing the observed change rates with the general synoptic circulation. Within the scope of these studies, the following graphs were obtained for the analysis of annual snow height and the number of snow-covered days in the Euphrates basin for many years (1950–2010).

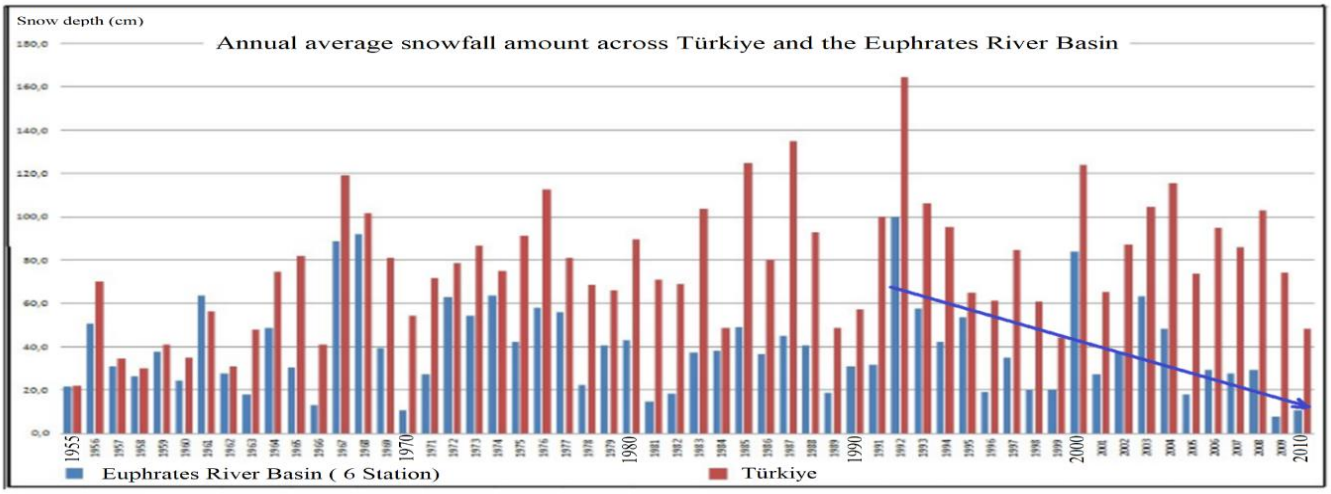


Fig 8 Annual average snowfall amount across Türkiye and the Euphrates River Basin [4].

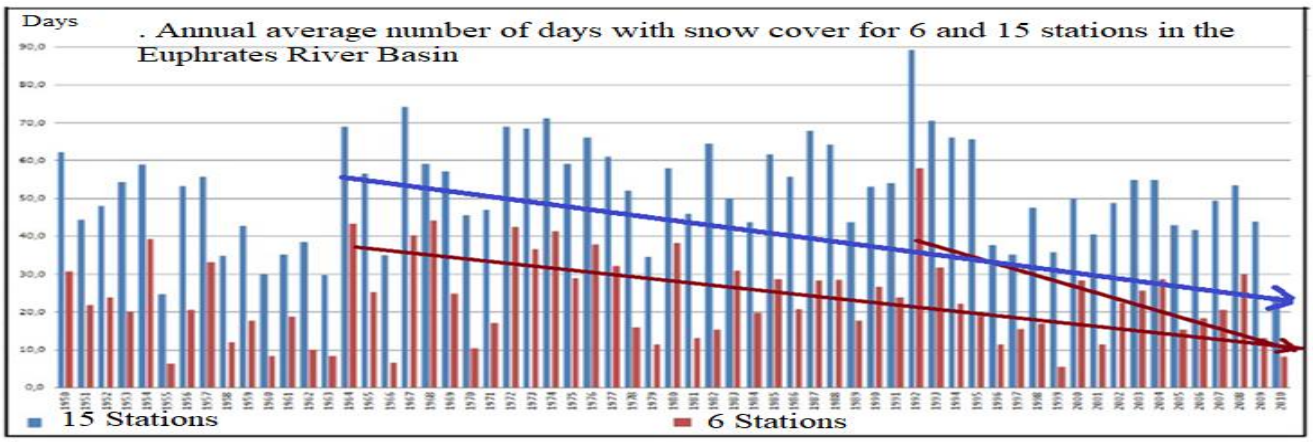


Fig 9 Annual average number of days with snow cover for 6 stations in the Euphrates River Basin [4].

In the analysis made on these graphs and other results given in Fig.8 and Fig.9, ıt was obtained that "While snowfall in some years for Türkiye in general has been above average compared to the long-term average, the average amount of snowfall in the stations in the Euphrates river basin is in a decreasing trend." (MGM 2023 b). In Fig.8 and 9, it is clearly seen that both the annual average snowfall amount and the number of snow-covered days have been in sharp decline from 1992 to 2010. When we look at the values for many years (1950–2010) in the number of snow-covered days given in Fig.9, we see a clear decreasing trend when the year 1992 is excluded. This trend an be taken into account as a very important indicator regarding the water budget of dams on the Euphrates River, which is fed by snowmelt.

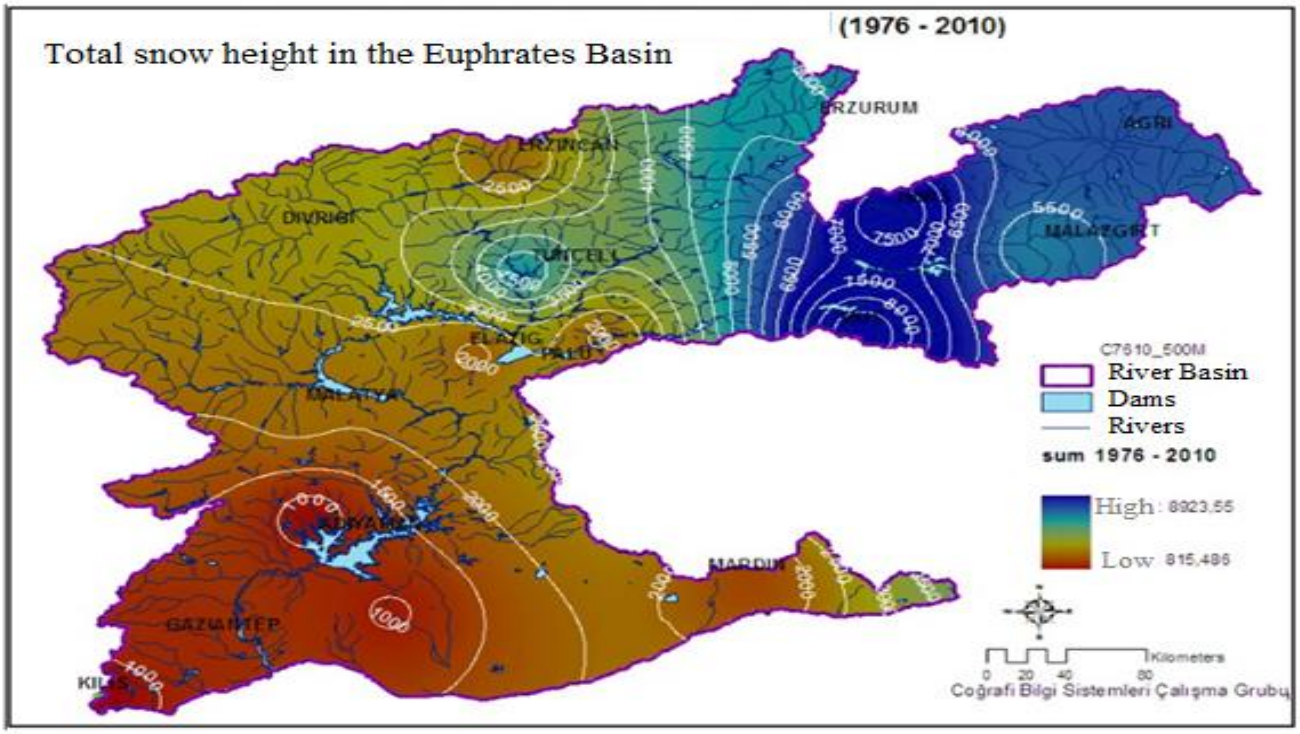


Fig 10 Total snow height in the Euphrates River Basin [4}.

In the studies carried out by MGM, total snow height maps were prepared in the Euphrates basin between the years 1976 and 2010 (Fig.10).

- *The effect of the decrease in precipitation in the Keban Dam watershed:-*

Apart from the reasons explained above, the most plausible reason for the gradual decrease in electrical energy generated in dams is the decrease in precipitation in the watershed. Dramatic decreases in the water levels of Keban and Atatürk Dams from time to time in the last 30 years have also occurred as a result of these meteorological drought periods. It is a natural consequence that this situation is reflected in the decrease in electrical energy generated from these dams. In addition to this result the results of the Long-Term Flow Trends Analysis of the Upper Euphrates Basin (Yildiz 2019) also revealed a natural tendency for long-term streamflow to decrease with temperature and precipitation in the Upper Euphrates River Basin. In the study, due to the complexity of creating a comprehensive basin-wide hydrological model, stream data were used in regression and time series analyses to estimate long-term flow trends. It was concluded that the annual natural flow in the basin tends to decrease, mainly due to natural factors.

## V. STUDIES ON IMPACT OF CLIMATE CHANGE IN THE TIGRIS AND EUPHRATES BASIN

In the literature, the temporal and spatial variations of hydrometeorological parameters in the Euphrates and Tigris River Basin have been studied by several researchers.

Yürekli [21]examined the changes in precipitation of 19 stations in ETRB at seven different time scales and determined a general decreasing trend. Önol and Semazzi (2009) found that precipitation in the Türkiye part of ETRB showed a strong decrease. Bozkurt and Şen [18] determined that precipitation data in the Euphrtaes and Tigris River Basin decreased in the mountainous and northern parts of the basin[14].

Daggupati et al.[22] analyzed the temporal and spatial distribution of streamflow and precipitation data by dividing the Basin into three sub-regions. A 30, 24 and 16% reduction in precipitation was obtained for zone 1 (on the borders of Türkiye), zone 2 (on the borders of Iran) and zone 3 (on the borders of Syria and Iraq), respectively[14] .

Among other researchers, Büyükyıldız made a very comprehensive study [14] on "Evaluation of annual total precipitation in the transboundary Euphrates–Tigris River Basin of Türkiye using innovative graphical and statistical trend approaches". As a result of the analyses, a decreasing trend was determined in all trend methods generally used in annual total precipitation for the period studied in Euphrates and Tigris River Basin. The results obtained from several analysis[1,6,14,15,16,17,18,19,20,21,22] also shows a high compatibility with her study result.

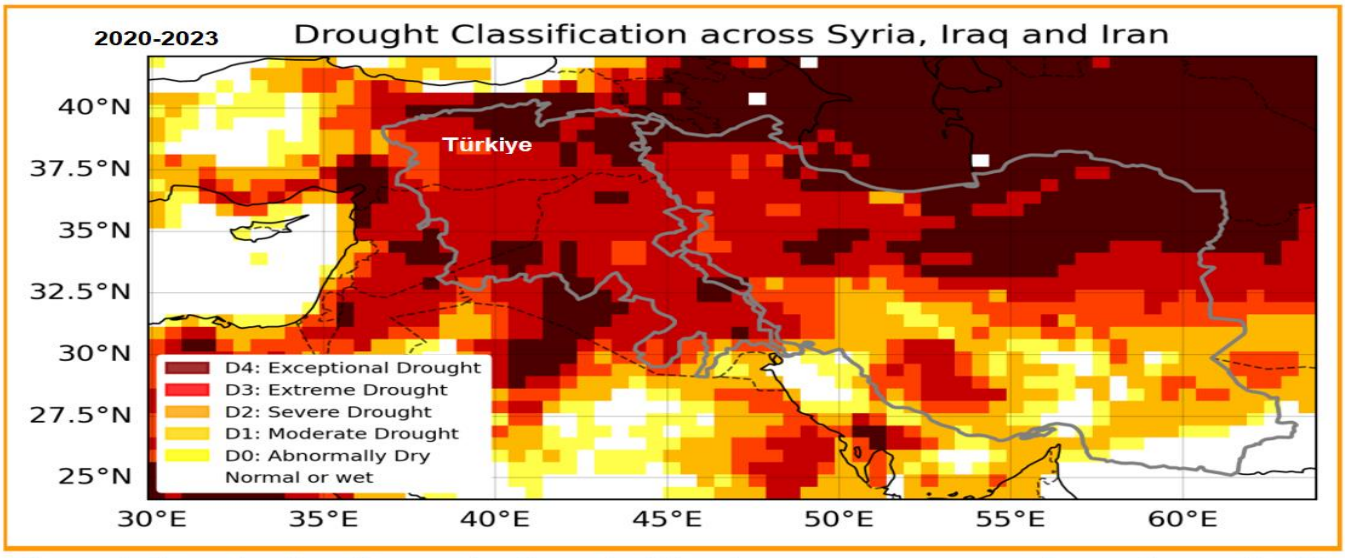


Fig 11 Drought classification for the Greater West Asia region according to the US global drought monitoring system[7].

The legend shows 36-month SPEI values in June 2023. Study regions, the Tigris-Euphrates River Basin, and Iran are shown with gray lines.

In the study conducted by the World Weather Attribution Group (Otto et al 2023), it was determined that there was an extreme and extraordinary agricultural drought in the entire Euphrates and Tigris Basin (ET-Basin) and a very large region of Iran for 36 months until June 2023. (Fig.11). In the study conducted using three different observation-based data sets, a strong trend towards more serious droughts in the future was detected both in the Tigris and Euphrates basins and in Iran. This study (Otto et al. 2023) used observation-based data to determine whether and to what extent human-caused climate change is a driver of drought trends in the region. These data were applied to climate models, and 36-month SPEI values in the region were obtained. In the study carried out by the World Weather Attribution Group (Otto et al. 2023), it was determined that the probability of such a drought occurring in the Tigris and Euphrates Basin recently increased by 25 times compared to a 1.2 ° C cooler world. In Iran, it was concluded that the probability of such a drought increased 16 times compared to a 1.2 ° C cooler world (Otto et al. 2023).

According to the results of the research, more serious droughts are expected to occur at least once every ten years, as the average temperature in the world has increased by 1.2 ° C, mostly due to the influence of fossil fuels.

- *The Impact of Climate Change Behind Extreme Droughts in Syria, Iraq and Iran (Otto et al 2023):-*

According to the results of a study conducted by the World Weather Attribution Group, droughts of this severity in the Tigris-Euphrates basin, which covers a large part of Syria and Iraq, were experienced approximately every 250 years before global warming. Now they are expected to happen once every ten years. While extreme droughts in Iran occurred once every 80 years in the past, in today's hotter world, they now occur on average every five years. In a study by the World Weather Attribution Group (Otto et al. 2023), researchers investigated how drought severity and recurrence time have changed in the Tigris and Euphrates basins and Iran since global warming has increased the average temperature by approximately 1,2°C. For this purpose, observation-based hydrometeorological data and climate models were used. Researchers in this study concluded that *it is "almost impossible" for the high temperatures recorded since 2020 to occur without climate change and that climate change makes drought much more likely to occur. The severity of drought detected in the Tigris and Euphrates basins for the last three years is classified as "extremely dry" on the US Drought Observation scale.*

In the article [7], researchers claimed that the extreme droughts that occurred in the last three years were caused by the effect of climate change and that if this effect had not occurred, the drought threshold would not have been crossed. Researchers state that it is vital to plan against droughts that will occur more frequently in the future. Prof. Mohammad Rahimi. from Semnan University in Iran stated that *"our study shows that human-induced climate change is making life very difficult for tens of millions of people in West Asia. With further warming, Syria, Iraq and Iran will become even more difficult places to live.*

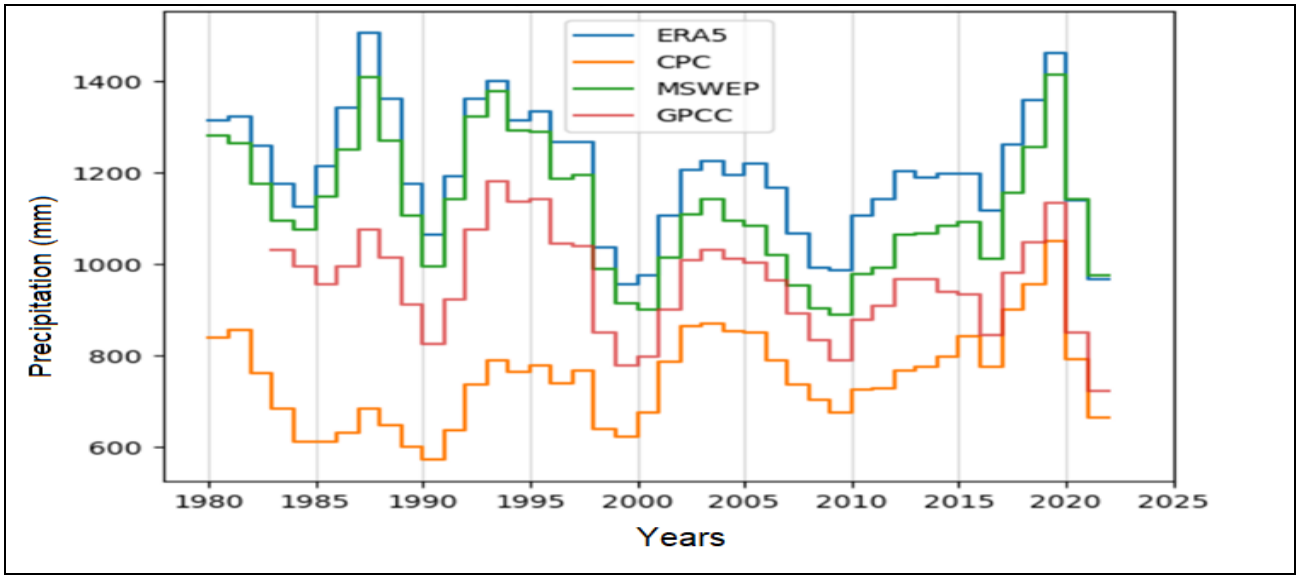


Fig 12 Change in three-year cumulative total precipitation in the Tigris-Euphrates Basin. (Data sets used: CPC, GPCC, MSWEP, ERA5) [7].

In this research, long-term precipitation data in the Tigris-Euphrates River Basin was also examined. Fig. 10 shows the time series of cumulative precipitation for the Tigris-Euphrates River Basin. Three of the data sets used in this analysis appear to show good agreement among themselves. Additionally, Fig. 10 shows that dry periods have occurred in the Euphrates-Tigris river basin since 1980 and that there has been a gradual decrease in cumulative precipitation.

In a World Bank Report [20] it is also stated that "*Considering that the decreases detected in precipitation and snowfall despite the increases in temperature and evapotranspiration in the studies conducted for the past time periods by various researchers on the region, will continue in the future, all riparian countries of the basin (especially in downstream countries such as Iraq and Syria largely rely on upstream water) water shortage, which is a problem even now, will increase in the future and cause serious pressures on water resources*"

It is obvious that the decreasing trends in precipitation and snowfall obtained in several studies related to the region has also significantly affected the flow rate and decreased hydroelectic energy in the region

As a result ,the findings obtained in this stud, on the decrease in hydroelectric energy generation, are also consistent with other literature findings on the decrease in precipitation and flow rate in the Euphrates River Basin

## VI. CONCLUSIONS AND RECOMMENDATIONS

Keban, Karakaya and Atatürk Dams are the most important dams on the transboundary Euphrates River in Türkiye. Of these three dams, the Keban Dam was put into operation in 1974, the Karakaya Dam in 1987, and the Atatürk Dam in 1992. The total installed capacity of these three dams is 5530 MW, or 17.5% of the total hydroelectric energy installed capacity in Türkiye.

They generate 11.80 GWh of hydroelectric energy, or 19% of the total hydroelectric energy in 2022. These three dams generate approximately one-fifth of the hydroelectric energy in Türkiye. With the start of generation of the Atatürk Dam in 1993, these three dams began to operate synchronously. The electrical energy operating program of these three dams has been planned synchronously since 1993, and it is aimed to reaching the highest level of total electricity generation. The annual project electricty generation capacities of Keban, Karakaya and Atatürk Dams are 6.6 GWh, 7.5 GWh, and 8.9 GWh, respectively, and the total project generation value of these three dams is 23 GWh.

There is a difference between the terms of project electricty generation capacity and reliable electrical energy generation in hydroelectric power plants. However, these dams, which have very large water storage capacities and located on the same river in line.This brings the advantage of being operated synchronously with each other. Therefore, energy generation can be achieved at the highest level with a well-planned operating program. In the five years following 1993, this generation reached at its highest level and then started to decrease gradually. These dams have produced below-project generation at various levels 17 times in the last 30 years. Among these dams, the Atatürk Dam had the highest gradual decrease in annual hydroelectric energy generation. Annual amounts at the Atatürk Dam in nine of the last 30 years were 45% below the 8.9 Gwh project generation capacity.

The annually generated electrical energy data used in this study was obtained from the web page www.enerjiatlasi.com/hydroelektrik and checked with other different sources. We obtained that there has been a gradual decrease in the total annual electricity generation of Keban, Karakaya and Atatürk Dams for the last 30 years.

This study aim to discuss the reasons for the continuous decrease in energy generation, including changes in flow rate, snow height, and recent scientific studies.The study (Yildiz 2019) conducted and published in 2019 on the change in flow rate in the region were also included in this evaluation. Changes and analyses in the annual average snow height obtained by the Türkiye General Directorate of Meteorology (MGM) in the Euphrates River basin were also examined. In addition, recent scientific studies (Yılmaz 2019) claiming that the drought in the Tigris- Euphrates basin occurred due to the effects of climate change were also evaluated.

The results of the study conducted by several reserachers on this subject [1,6,7,8, 10,14,15,16,17,18,19,20,21,22] and the analyses carried out by MGM gave compatible results regarding the hydroclimatological changes in the Tigris-Euphrates basin.

As a result, many effects that may cause a decrease in the energy generation of dams in the Euphrates Basin have been examined in detail, and it has been obtained that this gradual and continuous decrease is caused by the dry periods lead to decrease in precipitation in the basin. It is of great importance to examine in detail the effects of this climate change pressure on water resources in the region.

This study can be carried out in more detail by obtaining the monthly electricity generation data of Keban, Karakaya and Atatürk Dams for the last 30 years and the dam's reservoir water levels, to compare areal distribution of precipitation values in the dams watersheds.

Further work is urgently needed to integrate the latest climate projections to water resource planning and international water negotiations; analyses of South Eastern Anatolian Project (GAP) and other major development projects that fail to account for the changing climate reality of the region will underestimate risk and could lead to dangerously optimistic decision making.

According to the results obtained both in this study and in other scientific studies [1, 6,7,8, 10 ,14, 15 ,16 ,17,18, 19, 20 ,21, 22] , it is obvious that climate change has decreased precipitation and flow rate in the region. The adverse effects of climate change on water resource in the region is likely to continue and trigger social ,economic and international problems.Therefore it requires urgent water cooperation among all riparian countries on adaptation to climate change and a more efficient water resources management

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