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THE EFFECT OF DAM RESERVOIRS IN FIRAT BASIN TO THE OUTDOOR TEMPERATURE PARAMETERS OF THE REGION CITIES

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Abstract

In this study, the effect of Keban, Karakaya, Ataturk, Birecik and Karkamıs dam reservoirs to the outdoor temperature and relative humidity parameters of the region cities was investigated. For the determination of the outdoor temperature, the mean of the minimum temperatures were taken as the meteorological dates for January, February and December which are the coldest months of the year for winter condition and the maximum temperatures were taken for June, July, August, and September for summer condition. The outdoor temperature and relative humidity calculations of the cities were made for three observation processes based on the before and after of the Keban Dam water filling date, the Karakaya Dam filling date and the Atatürk Dam water filling date. Five provinces in the region, Elazig, Malatya, Diyarbakir, Mardin and Sanliurfa, were examined in the study. It was determined that for the summer and winter conditions, the weather of the region cities was changed by the effect of these reservoirs. The weather became cooler in summer and warmer in winter.

Key words: Keban Dam, Karakaya Dam, Atatürk Dam, outdoor temperature, humidity, meteorological data

1. Introduction

In the construction of heating installation projects, one of the data as the basis of the design is the outdoor temperature parameter. Outdoor temperature parameters of the cities and towns in prepared Turkey in the 1950s comply with the today's conditions. Higher population density in cities, green areas, industrialization and lakes and ponds, which were established later-on, cause changes in the outdoor temperature parameter by affecting the climate structure of the cities (Bicer**,** 2020). Dam lakes, which were established in the following period and have a large water surface, are an important factor that causes climate change in their region. There is a continuous heat and mass transfer between the water layer and the moving or stationary air mass passing over the lake surface due to the differences in temperature and humidity. As a result of this, lakes with large surfaces play an important factor with regards to changing the local climate (Bacanli & Tugrul, 2016). For this reason, it is deemed necessary to heat residences and industrial areas in cold weather, to cool them in hot weather (HVAC systems), and to update the project criteria for heating economy.

Firat River, one of the important rivers of the Eastern Anatolia Region, rises on the Murat River and Karasu River at an altitude of 3290 meters, passing through Erzincan, Tunceli, Elazig, Malatya, Diyarbakir, Adiyaman, Gaziantep and Sanlıurfa province, while following into the Persian Gulf. Its length is 2,800 km and a total of 6,396 MW of electricity is produced from 5 hydroelectric power plants (HEPP) through the river. This power is equal to the electricity generated from HEPPs with a rate of 30 832 percent in Turkey, and a rate of 8.288 percent of the total electricity consumption. Dams and HEPPs on the Firat River are given collectively in Table 1.

Table 1. Dams on the Firat River

Dam	**province/ district**	**lake volume (hm^3)**	lake area **(km^2)**	**installed power (MW)**
Keban Dam	Elazig-Keban	31000	675	1330
Karakaya Dam	Diyarbakir-Cungus	9580	268	1800
Ataturk Dam	Sanliurfa-Bozova	48700	817	2405
Birecik Dam	Sanliurfa-Birecik	1220	56.25	672
Karkamıs Dam	Gaziantep-Karkamıs	157	28.40	189

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In this study, outdoor temperature and humidity parameters for a total of five provinces close to reservoirs were investigated for summer and winter. In the calculations made, three observation processes were taken as basis, namely, Keban (1975), Karakaya (1988) and Atatürk Dam (1992) based on the formation dates of the lake area. As the first observation process of the study, the Keban Dam Lake, which was first built in the Firat basin, was examined for the period before (1965-1975) and after (1975-1988), which is the filling date of the Keban Dam Lake. In the second observation process of the study, taking into account the date of formation of the lake in Karakaya Dam in 1988 and the date of filling of the Atatürk Dam reservoir in 1992, new outdoor temperature parameters for the winter and summer conditions of the surrounding provinces were determined. The third observation process of the study is the calculations made for the period from 1992 to the present, as an example for Elazig province.

Many studies have been carried out on the subject and it is possible to collect these studies in two groups. The first group of studies are the ones that focus on investigating the effects of dam lakes on the climate structure of the provinces of the region. Some of these studies are the ones that examine the effect of Keban Dam Lake on the climate structure of Elazig province (Bicer, 2019), (Kadioğlu, 1994), (Tonbul, 1986), (Sengun, 2007), (Ozkan, 1996), (Emiroglu et al, 1996), (Akpinar, & Akpinar, 2010-a). Another group of studies comprise of those investigating the effect of Ataturk Dam Lake on the climate structure of Sanliurfa province (Bulut et al, 2010), (Ekici, 2008). The second group of studies are on climate structures (Bicer**,** 2021), Cobanyilmaz, & Yuksel, 2013), (Akpinar, & Akpinar, 2010-b). (Apple et al, 2006), (Emall et al, 2001), (Dodman, 2009), (Gyau-Boakye, 2001), (Yılmaz et al, 2007), (Fujihara et al, 2008), (Degu et al, 2011), (Bai et al, 2014).

Studies on the effects of the reservoirs in the study area on the climate structures of the surrounding provinces were carried out for a short period after the filling dates of the lake of the five dams. With this study, the impact of dams on the outdoor temperature and relative humidity parameters (summer and winter) of the surrounding provinces will be more realistic since it covers a long period (46 years).

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2. Features of Study Area

The area subject to the study is the upper Firat Basin. This area covers the north-west and south-west of the Southeastern Anatolia Region of Turkey's Eastern Anatolia region (Fig 1). The geographical features of Elazıg, Malatya, Diyarbakir, Mardin and Sanlıurfa provinces examined in the region are shown in Table 2.

Fig. 1. Geographical districts of Turkey (URL-1, 2021)

Table 2. Geographic location of meteorological stations

Location	Longitude east	Latitude north	Altitude (m)	Area (km^2)
Elazig	39.14	38.41	1067	9151
Malatya	38.19	38.21	977	12313
Diyarbakir	40.14	37.55	675	15355
Mardin	40.44	37.18	1083	8891
Sanliurfa	38.46	37.08	510	19336

Elazig province is located in the southwest of the Eastern Anatolia Region, in the Upper Fırat Basin Section. It is 25 km from the Keban Dam Lake and 45 km from Karakaya Dam Lake. Malatya is located in the same basin with Elazig province and at the southwestern end of the depression area of Adiyaman, Malatya, Elazig, Bingol, Mus and Van. Its distances from Keban and Karakaya dam lakes are 45 and 42 kilometers, respectively. Diyarbakir province is located in the central part of Southeastern Anatolia Region, in the north of Al Cezire (Mesopotamia). Its distance to Karakaya Dam Lake is 134 kilometers. The province of Mardin is located in the Tigris section of the Southeastern Anatolia Region. Its distance to Atatürk Dam Lake is 299 kilometers. Sanlıurfa looks like a plain in general. It is located in the south of the region on the Syrian border. Its distance to Atatürk Dam Lake is 71 km

3. Method Used To Determıne Outdoor Temperature

For the determination of the outdoor temperature parameter, the average of the lowest temperature averages of January, February and December for the winter season, and the average of the highest temperatures for the months of June, July, August and September for summer season conditions were taken as basis. Accordingly, outdoor temperature parameters have been determined (Bicer**,** 2020).

$$T_{odn}=(T_{min\ January} + T_{min\ Fabruary} + T_{min\ December}).(1/3) \quad (1)$$

$$T_{od}=(1/n).\sum Tdn \quad (2)$$

In here, T_{odn} is the average of the lowest average temperatures of January, February and December, and T_{od} is the outdoor temperature parameter of the region

The outdoor temperature parameter for summer conditions is calculated using the same equation by taking the average of the highest temperature averages of June, July, August and September. The calculations were repeated in the same way for relative humidity, as well.

3.1. Application of the Method on Elazig for Winter Season

The method to be used in determining the outdoor temperature parameter has been applied on the 5 investigated provinces. The calculations were made for the three observation processes mentioned above. As the first observation process of the study, in order to examine the effect of Keban Dam Lake on the climate of the region, the provinces of the region were examined separately according to the observation processes before (1965-1975) and after (1975-1988), which is the filling date of the lake. Within the scope of the third observation process of the study, new outdoor temperature parameters were calculated for the winter conditions of the provinces examined until today, taking into account the lake formation date of the Karakaya Dam in 1988 and the filling date of the Ataturk Dam reservoir in 1992. Table 3, Table 4 and Table 5 are shown as an example for Elazig province. Using the same method, the outdoor temperature values of the provinces were researched for summer conditions, and the results are given in Table 6.

Table 3. 1965-1974 observation period outdoor temperature determination table for Elazig province

No	Years	$T_{January}$ (°C)	$T_{Fabruary}$ (°C)	$T_{December}$ (°C)	Tdn (°C)	Relative humidity (%)
1	1965	-10.2	-8.3	-7.2	-8.57	77.33
2	1966	-13.4	-3.0	-6.5	-7.9	72.66
3	1967	-10.0	-18	-9.8	-12.6	74.66
4	1968	-15.2	-16.5	-1.5	-11.06	78.33
5	1969	-14.8	-13.9	-4.0	-10.9	77.66
6	1970	-6.4	-6.3	-9.3	-7.33	76.66
7	1971	-6.8	-12.2	-10.8	-9.93	68.66
8	1972	-22.6	-21.4	-7.8	-17.26	66.00
9	1972	-18.5	-7.2	-13.1	-12.94	74.00
10	1974	-16.9	-19.3	-5.6	-13.94	79.66
					$\sum$ Todn=-112.43	74.56 %

T_{od}= (1/10).(-112.43)= -11.25 (°C)

Table 4. 1975-1988 observation period outdoor temperature determination table for Elazig province (TMSD, 2020).

	Years	**T$_{January}$ (°C)**	**T$_{Fabruary}$ (°C)**	**T$_{December}$ (°C)**	**Tdn (°C)**	**Relative humidity (%)**
1	1975	-8.3	-12.6	-8.6	-9.83	70.66
2	1976	-13.6	-15.9	-4.7	-11.4	77.00
3	1977	-9.4	-3.7	-9.1	-7.4	73.66
4	1978	-9.0	-4.4	-3.1	-5.5	74.66
5	4979	-8.9	-8.3	-5.7	-7.64	72.33
6	1980	-14.4	-14.1	-6.5	-11.66	75.66
7	1981	-6.0	-3.4	-2.3	-3.9	75.00
8	1982	-10.5	-10.0	-6.2	-8.9	65.00
9	1983	-12.6	-12.8	-5.2	-10.2	73.00
10	1984	-4.4	-5.2	-7.6	-5.74	69.00
11	1985	-8.0	-17.2	-5.8	10.34	76.00
12	1986	-8.0	-7.0	-6.0	-7.0	77.66
13	1987	-10.8	-5.6	-10.2	-8.87	77.00
14	1988	-7.8	-5.6	-8.4	-7.27	76.66
					∑ Todn=-115.65	73.80%

T_{od}= (1/14).(-115.65)= -8.26°C.

Using the same method, the relative humidity values of the provinces were researched for winter and summer conditions, and the results are given in Table 6.

Table 5**.** 1988-2019 observation period outdoor temperature determination table for Elazig province (TMSD, 2020).

No	**Years**	**T$_{January}$(°C)**	**T$_{Fabruary}$ (°C)**	**T$_{December}$ (°C)**	**Tdn (°C)**	**Rel. humidity (%)**
1	1988	-7.8	1.4-5.6	-8.4	-7.2	75.66
2	1989	-8.6	-6.9	-5.7	-7.06	64.66
3	1990	-7.9	-6.7	-5.4	-6.66	69.66
4	1991	-7.5	-8.5	-4.3	-6.76	70.66
5	1992	-8.4	-9.3	-5.1	-7.6	72.86
6	1993	-7.9	-7.4	-4.3	6.53	71.46
7	1994	-7.2	-8.4	15.3	-10.3	70.33
8	1995	-5.2	-4.4	-4.8	-5.13	72.44
9	1996	-3.9	-5.8	-3.8	-4.37	71.87
10	1997	-4.2	-5.0	-4.3	-4.77	71.34
11	1998	-4.8	-5.7	-3.2	-4.34	73.47
12	1999	-4.4	-5.9	-4.7	-4.94	71.1
13	2000	-5.5	-4.7	-1.4	-4.27	71.6
14	2001	-4.4	-4.0	-4.1	-4.4	70.97
15	2002	-6.4	-4.4	-5.7	-5.37	68.97
16	2003	-4.5	-4.8	-4.5	-4.47	71.84
17	2004	-4.2	-4.7	-3.7	-4.24	72.27
18	2005	-4.5	-5.1	-3.8	-4.34	69.94
19	2006	-4.1	-4.2	-4.2	-4.47	70.74
20	2007	-5.5	-8.8	-3.9	-4.54	67.74
21	2008	-5.1	-4.5	-3.0	-5.64	65.64
22	2009	-4.3	-4.8	-3.7	-4.17	71.5
23	2010	-4.2	-5.3	-3.3	-4.1	71.67
24	2011	-3.4	-5.0	-3.5	-4.07	72.14
25	2012	-4.4	-3.5	-2.8	-4.07	71.74
26	2013	-3.2	-4.4	-4.4	-3.7	70.94
27	2014	-3.4	-3.1	-3.8	-3.87	71.7
28	2015	-3.7	-4.1	-3.2	-3.34	69.87

29	2016	-4.1	-4.3	-3.9	-4.04	70.2
30	2017	-3.7	-4.2	-3.9	-3.97	68.37
31	2018	-3.4	-4.0	-3.8	-3.8	67.47
32	2019	-3.5	-3.8	-3.6	-3.7	66.56
					∑ Todn=-160.23	**70.54**%

T_{od}= (1/32).(-160.23)= -5.007 ºC

Table 6**.** Temperature and relative humidity values for various observation periods of the provinces

Province	**Parameters**	**Currently used**	**1965-1975**	**1975-1988**	**1988-2019**
Elazig	Temperature (Winter)	-12ºC	-11.25ºC	-8.26ºC	-5ºC
	Temperature (Summer)	+38ºC	+38ºC	+36.8ºC	34ºC
	R. humidity (Winter)	75 (%)	74.56 (%)	73.80 (%)	70.54 (%)
	R. humidity (Summer)	30 (%)	28.85 (%)	32.46 (%)	35.17 (%)
Malatya	Temperature (Winter)	-12ºC	-12.13ºC	-8.20ºC	-5ºC
	Temperature (Summer)	+38ºC	+38ºC	+36.61ºC	34ºC
	R. humidity (Winter)	75 (%)	73.73 (%)	73.66 (%)	70.16 (%)
	R. humidity (Summer)	30 (%)	28.36 (%)	33.93 (%)	35.22 (%)
Diyarbakir	Temperature (Winter)	-9ºC	-8.37ºC	-7.05ºC	-4.5ºC
	Temperature (Summer)	+42ºC	+42.6ºC	+41.83ºC	39ºC
	R. humidity (Winter)	77 (%)	76.79 (%)	75.92 (%)	71.88 (%)
	R. humidity (Summer)	32 (%)	31.27 (%)	34.26 (%)	36.18 (%)
Mardin	Temperature (Winter)	-6ºC	-5.65ºC	-4.95ºC	-2ºC
	Temperature (Summer)	+38ºC	+38.8ºC	+38.6ºC	36ºC
	R. humidity (Winter)	70 (%)	69.09 (%)	68.09 (%)	66.88 (%)
	R. humidity (Summer)	26 (%)	25.32 (%)	30.78 (%)	32.86 (%)
Sanliurfa	Temperature (Winter)	-6ºC	-5.54ºC	-5.33ºC	-1ºC
	Temperature (Summer)	+43ºC	+43.3ºC	+38.35ºC	37ºC
	R. humidity (Winter)	72 (%)	71.8 (%)	70.2 (%)	68.44 (%)
	R. humidity (Summer)	32 (%)	32.5 (%)	33.24 (%)	37.42 (%)

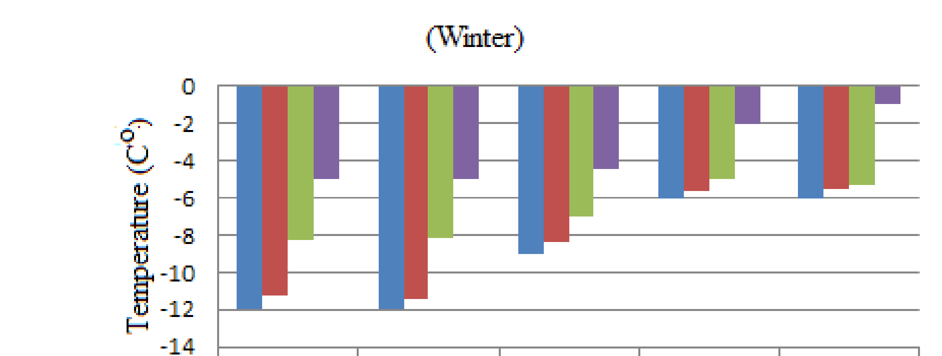
3. Results and Discussions

Examining Table 3, the calculation results for the process before the construction of the dams in the region are close to the outdoor temperature values of winter and summer conditions that are given in the literature yet still in use. In Table 4, it can be seen that Keban Dam Lake has an effect on the outdoor temperature parameter of the provinces of Elazig and Malatya after 1975 for the observation periods of 1975-1988 and this effect is an average of -8ºC for the winter season. As the distance to the lake increases, this effect decreases and as a matter of fact, while a warming close to 1.95ºC was observed in Diyarbakır, which is 151 km away, it did not affect Mardin and Sanlıurfa provinces (Fig 2-a).

After 1988, with the formation of the Karakaya Dam reservoir area only, Elazig and Malatya provinces warmed by 1ºC, while a 2ºC warming rate was provided for Diyarbakır (Table 5, Fig. 2-a).

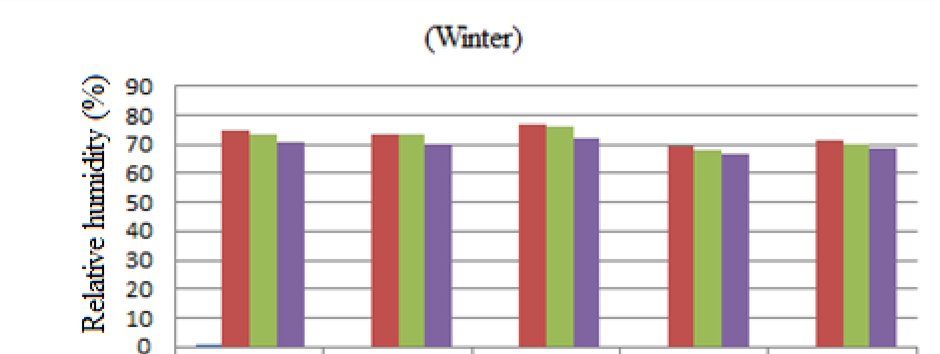
Ataturk and four other dams affected the new outdoor temperature parameter during the observation processes until 2020, causing warming rate of 7ºC for Elazig and Malatya provinces, 4.5ºC for Diyarbakır, and 4ºC for Sanliurfa and Mardin. As can be seen in Table 6 and Fig.3-a, five dams caused a cooling of 3.5ºC in Elazig and Malatya provinces, and 2.5 ºC in Diyarbakır, 6.5ºC in Sanliurfa and 2ºC in Mardin in summer conditions.

As of the formation dates of the dams, the average relative humidity rates have decreased by 2% in Elazig, Malatya and Mardin provinces in the winter season, Diyarbakir by 5%, Sanliurfa by 3%, while in the summer it has increased by 7% in Elazig, Malatya and Mardin and by 5% in Diyarbakır and Sanliurfa provinces (Fig.2-b and Fig.3-b).



	Elazig	Malatya	Diyarbakir	Mardin	Sanliurfa
Currently used	-12	-12	-9	-6	-6
1965-1975	-11.25	-11.4	-8.37	-5.65	-5.54
1975-1988	-8.26	-8.2	-7.05	-4.95	-5.33
1988-2019	-5	-5	-4.5	-2	-1

Fig. 2-a. Temperature values in winter season in observation processes



	Elazig	Malatya	Diyarbakir	Mardin	Sanliurfa
1965-1975	74.56	73.73	76.79	69.09	71.8
1975-1988	73.8	73.66	75.92	68.09	70.2
1988-2019	70.54	70.12	71.88	66.88	68.44

Fig. 2-b. Humidity values in winter season in observation processes

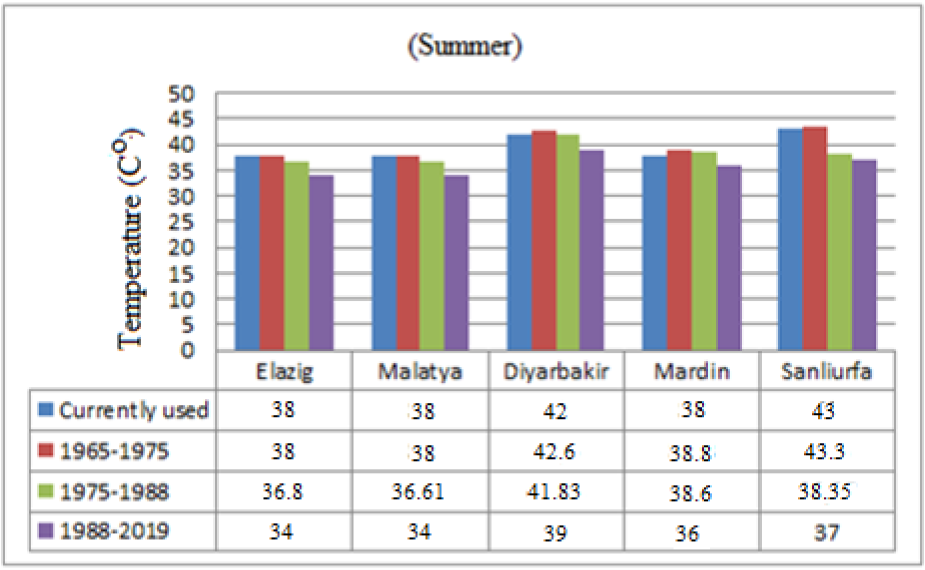


Fig. 3-a. Temperature values in winter season in observation processes

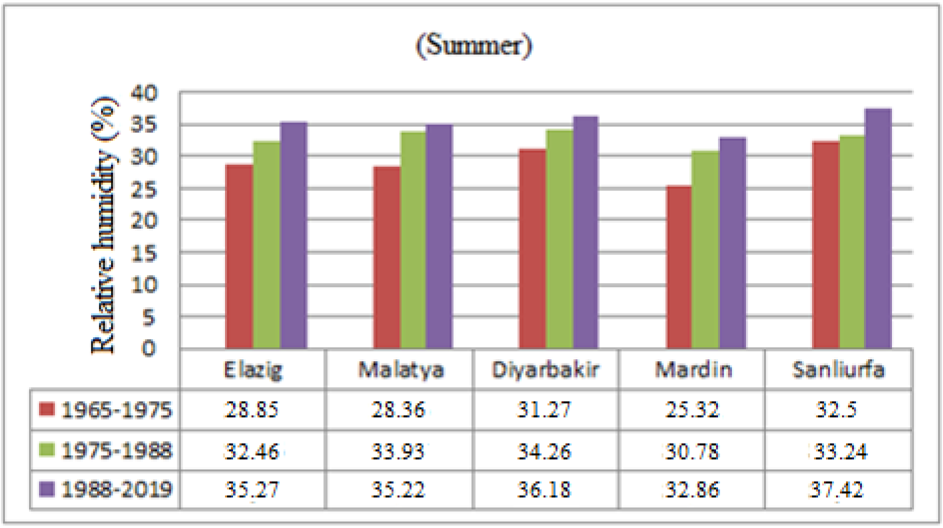


Fig. 3-b. Humidity values in winter season in observation processes

Analysis of New Outdoor Temperature Parameters:

A duplex building constructed in Elazig province is taken as example. The building will be heated with natural gas. In the project, there is a living room and kitchen on the ground floor, and three bedrooms and bathrooms in the upstairs. Separate heat calculations results by using Eq 3, Eq 4 and Eq 5 taking the existing outdoor temperatures as -12°C, -9°C and -5°C are given in Table 7.

$$Q_T = k.F.(T_i - T_d).Z \quad (3)$$

$$Q_L = (a.L).R.H.Z_E.(t_i - t_d) \quad (4)$$

$$Q_h = Q_T + Q_L \quad (5)$$

Here,

Q_t ; Heat losses from building materials of a location, Q_L; heat losses caused by ventilation, Q_h;The sum of the two heat losses k; thermal conductivity coefficient of building material, F; surface area, T_i; internal temperature, T_d: outdoor temperature, Z; percentage of heat increase due to building direction and operation, a, L, Z_E coefficients for air leakage of windows and doors, R and H are room and building coefficients.

Table **7.** Energy needs of the rooms according to the outside temperatureı (W)

Room name	**Temperature (ºC)**	**-12ºC**	**-9ºC**	**-5ºC**
Living room	22	4926	4615	4006
Kitchen	18	1742	1612	1125
Bedroom 1	20	1765	1586	1166
Bedroom 2	20	2543	2273	1797
Bedroom 3	20	1849	1664	1242
Bathroom	26	1338	1257	997
	Total	**14153**	**13007**	**10333**

Comparing the calculations made for outdoor temperature of -5 ºC and the results of -12ºC, the savings rates to be achieved can be seen in Table 8.

Table 8**.** Savings calculated according to the new outdoor temperature (-5ºC) parameter

Saving type	Saving rate (%)
Hourly heat needs	26.99
Fuel consumption	26.5
Boiler and heater capacity	26.2

4. Conclusions

Dams lakes built on the Firat River caused the climate of the region to change. With the calculations made using meteorological values, the lakes formed later affected the outdoor temperature and relative humidity parameters of the neighboring provinces and the following results were obtained:

✓ With the calculation method used, values close to the outdoor temperature parameter given in the studied provinces in the literature for the years before the construction dates of the dams were obtained.

✓ Due to the formation of the Keban Dam Lake in 1975, in Elazig and Malatya provinces, the outdoor temperature parameter increased under winter conditions by 3ºC 1.95ºC for Diyarbakır province, and Elazığ and Malatya provinces, while causing a decrease (cooling) approximately 2ºC for summer season. It cannot be said that this situation has an effect on other provinces of the region. In 1988, Karakaya, in 1992, with the construction of the Atatürk Dam Reservoir and later Birecik and Karkamıs dams, and the total effect of the outdoor temperature parameter caused an increase of (with five dam lakes) 7ºC under winter conditions in Elazig and Malatya provinces and 4.5ºC in Diyarbakır, 4ºC for Mardin and 5ºC for Sanliurfa.

✓ Due to the Dam Lakes, a cooling of 4ºC was experienced in Elazığ and Malatya provinces, 3ºC in Diyarbakır, 2ºC in Mardin and 5ºC in Sanliurfa for the summer season.

✓ At the end of the filling of the five dam reservoirs, the rate of decrease in the relative humidity in the air of the provinces examined is 5.4% in Elazig, 4.84% in Malatya, 6.3% in Diyarbakir, 3.19% in Mardin and 4.67% in Sanliurfa for the winter season. The increase rates for the summer season are 22.25% in Elazig, 24.18% in Malatya, 15.7% in Diyarbakir, 29.6% in Mardin and 15.13% in Sanliurfa.

✓ At the end of the filling of the five dam reservoirs, for the winter season, the new outdoor temperature parameter is as follows: –5ºC for Elazig and Malatya provinces, –4ºC for Diyarbakır, –2ºC for Mardin and -1ºC for Sanliurfa. The outdoor temperature parameter for the summer season is as follows: + 34ºC for Elazig and Malatya provinces, + 39ºC for Diyarbakır, 36 ºC for Mardin and + 37ºC for Sanliurfa. Analyzing these results, based on the calculations made for Elazig province by means of using the new outdoor temperature value within the scope of winter conditions, it was determined that a saving of 26% of fuel and installation elements would be achieved.

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