Acta Aquatica Turcica

Home Page: https://dergipark.org.tr/actaquatr
E-ISSN: 2651-5474
22(2): 220205, 2026
DOI: 10.22392/actaquatr.1807631

Research Article **Araştırma Makalesi**

A Basin-Based Risk Assessment for Rainbow Trout Farming Based on the Türkiye Basin's Water Reserve Trend and Climate Indicator

Gürkan Diken[1,*]

[1]Fisheries Application and Research Center (SURAM) & Department of Aquaculture, Eğirdir Fisheries Faculty, Isparta University of Applied Sciences, Eastern Campus, 32260 Isparta-TÜRKİYE

*Corresponding Author: gurkandiken@isparta.edu.tr

Received: 20.10.2025 **Accepted:** 24.03.2026 **Published:** 01.06.2026

How to Cite: Diken, G. (2026) A basin-based risk assessment for Rainbow Trout farming based on the Türkiye basin's water reserve trend and climate indicator. *Acta Aquatica Turcica, 22*(2), 220205. https://doi.org/10.22392/actaquatr.1807631

Abstract: In this study, trout production of Türkiye in the last decade is evaluated. The predicted climatic and hydrological changes in Türkiye's River Basins are addressed with the 2024 rainbow trout production data, and production strategies, regional planning, policy and management of sustainable aquaculture in risky and potential regions are emphasized. Inland aquaculture still maintains its strategic importance in rainbow trout production, which is shifting towards the marine areas of the Black Sea. Inland water rainbow trout production is steadily increasing in two-centered inland rainbow trout production encompassing Muğla and Elâzığ provinces. Of the 22 basins with 1% or more production in inland rainbow trout farming, 12 are at risk due to the effects of climate change. Six basins may be in a strategic position for future production. In Türkiye, basin planning should be carried out for the sustainability of rainbow trout farming in the latitudes below 39°-40° N, based on 35° E longitude, and centered in Muğla and Elâzığ, and modern systems should be implemented to minimize water use, and climate-resistant strategies should be developed.

Keywords
- Elâzığ
- Muğla
- Inland water
- Sustainability
- Trout

1. INTRODUCTION

Türkiye's total aquaculture production increased from 79,031 tonnes in 2000 to 557,124 tonnes in 2024. Trout farming (including rainbow trout, *Oncorhynchus mykiss* and *Salmo* sp.) in both inland and marine areas accounts for the largest share of this production. Although the share of trout in this production decreased from 56.35% to 40.13% during the same period, the production amount increased by 420.04%. Although the share of inland water trout in trout farming decreased from 95.60% to 73.80%, production continues to be largely concentrated in inland waters (TSI, 2025). Thanks to this successful production and related policy support, Türkiye is the second largest producer of rainbow trout and the world leader in the production of European sea bass and gilthead sea bream (FAO, 2026). Türkiye's strategic location and the biodiversity of the Mediterranean Basin have been influential in this success (Çelik and Akmermer, 2021). Other factors in this success are related to the know-how and experience in aquaculture and feed production (Knudsen, 2025). Since 2014, Türkiye has shifted its national aquaculture production to marine areas (FAO, 2026; TSI, 2025; TRAF-GDFA, 2026a).

A large part of Türkiye's geography falls within the Csa Köppen climate class with mild winters, very hot and dry summers-Mediterranean climate (Bölük et al., 2023). Türkiye's location in the temperate region and the Mediterranean Basin makes it vulnerable to the effects of climate change. Furthermore, global agriculture, forestry, and fisheries also carry a high level of climate risk and vulnerability (World Bank Group, 2022). While the World Meteorological Organization defines climate as the statistical averages and variability of weather events over 30 years or more, climate change is defined as changes observed in the climate of a region or the world over decades or longer. The United Nations Framework Convention on Climate Change attributes climate change to human activities rather than natural conditions (IPCC, 2018). The status of water management, which is based on resource allocation, may change due to climate change and land-use changes. Therefore, dynamic and synergistic approaches should be determined for water, energy, and food resources, which are highly interdependent (Mohtar and Fares, 2022). Türkiye's water reserves are expressed as a total of 112 billion m³ of usable surface and groundwater, of which 95 billion m³ is domestic surface water, 3 billion m³ is usable surface water from neighbouring countries, and 14 billion m³ is groundwater (TRAF-GDWM, 2020). Of the annual water consumption of 57 m^3, 77% is used for irrigation and 23% for drinking, domestic use, and industrial purposes (TRAF-GDSHW, 2024). The water needs of rivers in some basins that make up Türkiye's water resources have reached source insufficiency. Overuse of groundwater and climate change will negatively affect the future of water resources (TRAF-GDWM, 2020). Natural events such as droughts, as well as human-induced events such as water extraction, deterioration of water quality, and problems with access to water, and climate change resulting from both events, are sources of water stress (EEA, 2021). Water stress will have the greatest impact in the Iberian Peninsula and Anatolia, with a 3°C increase in temperature in Europe (EEA, 2021). It has been reported that Türkiye's water stress value in 2030 will be in the severe water stress (index value above 40%) and medium water stress (index value 20-40%) categories based on river basins (García-Valiñas et al., 2010, citing Henrichs et al., 2007). Another study reported that most of Türkiye's River Basins will fall into the high stress category (index value 40-80%), with a secondary level of medium-high stress (index value 20-40%), and that some basins will reach the extremely high stress level (80% and above) (Meißner, 2021, citing Gassert et al., 2013). On the other hand, it is reported that more than 60% of Türkiye's land is vulnerable to desertification and is at critical risk, while only approximately 12% is unaffected by desertification risk (Uzuner and Dengiz, 2020). The distribution of desertification risk levels is as follows; low-risk areas are 12.7%, medium-risk areas are 53.2%, and high-risk areas are 25.5% (Türkeş et al., 2020). These reports indicate that farms using groundwater or surface water in the inland waters of provinces with high levels of aquaculture production in Türkiye are at risk. According to the EEA (2021), implementing ecologically based river basin and drought management plans, as well as improving water-use efficiency, are critical for adapting to the effects of climate change.

Türkiye, one of the World's leading countries in inland aquaculture and particularly rainbow trout farming, faces threats to the sector's sustainability due to climate change-induced water scarcity, rising temperatures, and ecosystem changes. Based on this reality, this study evaluates climate and hydrological changes projected for Türkiye's hydrological basins for the period 2071-2100, along with rainbow trout production data for each province as of 2024. Risky and potential areas are identified, and recommendations for sustainable aquaculture are developed. The risk status of Türkiye's inland rainbow trout aquaculture in the face of climatic vulnerability is demonstrated on a basin-by-basin basis.

2. MATERIAL and METHODS

This study employed document (secondary data) analysis, a quantitative research method. The topic is based on an integrated analysis of long-standing and researched bibliographic and statistical data. The data were evaluated using comparative analysis methods, and a basin-based risk classification of rainbow trout in Türkiye's inland waters based on climate indicators was demonstrated. The processing of the data used is described below:

(1) The last 10 years of trout farming data in Türkiye between 2015 and 2024 (Table 1) (TSI, 2025) was used to evaluate annual growth rates-year-over-year to year (YoY) and average annual growth rate (AAGR). The YoY (%) was calculated by comparing the increase in current production to the previous year. The AAGR represents the arithmetic average of 10-year production. The inland trout farming data by province and species is displayed as Microsoft Excel mapping (Figure 1, 2, 3) (TSI, 2025).

(2) The production density and basin-based distribution of provinces with a 1% or greater share of Türkiye's inland rainbow trout production in 2024 is shown in Table 2 (TSI, 2025; TRAF-GDWM, 2025a, b, c, d, e, f). However, due to different values in the sources used in the evaluation of the basin areas (TRAF-GDWM, 2025a, b, c, d, e, f), the areas within the river basins of the provinces were evaluated with an approximate percentage scaling of the basins. The sections of the provinces falling within the basin area (approximate percentage values) were

correlated using a scoring test. The average score in the correlation was 3 provinces (Table 2). According to the scoring, a provincial section within the basin area was classified as low if it was 1 or 2, medium if it was 3 basins, and high if it was 4 or above (Table 2; Figure 2). The share of the Maritsa (Meriç)-Ergene, Marmara, Susurluk, Northern Aegean (Kuzey Ege), and Sakarya Basins in Türkiye's 2024 inland rainbow trout farming projected for inland waters was either below 1% or no production was carried out in the provinces included in these basins (Figure 1; Supplementary Table 1). In the data evaluation in Table 2, a total of 233 PDF files related to Turkish River Basins belonging to the General Directorate of Water Management, the Ministry of Agriculture and Forestry, were examined. These included drought management for 20 basins, flood management for 24 basins, river basin management for 12 basins, conservation actions for 9 basins, sectoral water allocation plans for 9 basins, and promotional brochures for 25 basins (TRAF-GDWM, 2025a, b, c, d, e, f). The approximate percentages of the provincial areas included in the basin were determined using 98 PDF files with similar relationships in these documents. Table 2 groups the provinces with a production share of 15% or more (1), the provinces with a production share between 3% and 8% (2), the provinces with a production share between 2% and 1% (3) and the provinces with a production share below 1% (4).

(3) Figure 4 shows the distribution of inland rainbow trout farming basins in Türkiye, latitudes below 39°-40° N, based on 35° E longitude, and centered in Muğla and Elâzığ.

(4) The precipitation amounts for 25 hydrogeological basins in Türkiye (TRAF-GDSHW, 2024) and the temperature, precipitation, water reserve, and groundwater projections for these basins for the 1971-2000 period and for the years 2041-2070 and 2071-2100 (Supplementary Table 2) (TRAF-GDWM, 2020) were used to classify the basins according to whether each parameter was above or below the basin-wide average value. The classification results were visualised using a Sankey flow diagram to show the transition from basin identity to the parameter categories above and below the average value (Figure 5, 6, 7, 8).

(5) Meteorological data on Türkiye's atmospheric temperature and precipitation are presented in Figure 9 (TSMS, 2025a).

(6) Data were evaluated using comparative analyses, and the risk assessment of rainbow trout in Türkiye's inland waters was organised in Table 3, with the parameters in Figure 5, 6, 7, 8 scored on a basin-by-basin basis. Above-average temperature (1), precipitation (1), water reserve (1), and groundwater reserve (0.5+0.5) were included in the scoring. Maximum values above average in temperature were considered. Expected temperature increase values were included in the scoring as half a point (0.5) if the temperature increase was above average, even though it was below the average values.

3. RESULT and DISCUSSION

3.1. Trends of Türkiye's trout production (2015-2024)

Trout production in Türkiye increased by 114.36% between 2015 and 2024, from 108,038 tonnes to 231,591 tonnes ($y=15197.08x-30538110.81$; $R^2=0.9095$; *where x is year, y is production*) (Table 1; Figure 1, 2, 3). While inland production maintained a stable and high share, marine production showed periods of relatively faster proportional growth. Rainbow trout farming accounted for 98.71% of this production, while *Salmo* sp. accounted for 1.29%. As of 2021, *Salmo* sp. farming was not carried out in marine areas (Table 1). The increase in inland production could not prevent its share in total production from decreasing from 93.64% to 73.80%, while production in marine areas increased from 6.36% to 26.20%. This situation in trout farming shows that production is shifting towards marine areas and demonstrates the development of the potential of aquaculture in Türkiye's existing marine areas. The YoY calculations pointed to a faster increase in marine production (Table 1). The 2019 and 2020 YoY rates for inland rainbow trout suggest that the sector has achieved its high production targets for these years. A similar situation occurred in 2024 (Table 1). Generally speaking, the 10-year AAGR was 6.06% and 35.30% in inland and marine areas, respectively (Table 1). According to YoY and AAGR values, the increase in marine production may be related to technological advances and supportive policies. These relative differences in the share of inland waters may be attributed to spatial, aquaculture issues, environmental, or strategic reasons. Rainbow trout has supported this growth thanks to both its adaptability to environmental conditions and high market demand. Consequently, inland water production has maintained a stable and high share, while marine production has shown more dynamic development (Table 1; Figure 1, 2, 3).

3.1.1. Regional distribution of inland trout farming in Türkiye (2015-2024)

Rainbow trout production in the 22 provinces with a share of 1% or more in production increased from 84,129 tonnes to 155,305 tonnes (84.60% increase) in the 2015-2024 period, and the total production in this period was recorded as 1,100,506 tonnes (Table 2; Figure 2). The distribution of total inland rainbow trout production in Table 1 is presented by province in Figure 1, indicating no farming in the provinces of Istanbul, Nevşehir, Tekirdağ, Aksaray, Kırıkkale, and Kilis. Although production is geographically spread over a wide area, most of the production is concentrated in provinces located predominantly below 39°-40° N latitude (Figure 4). According to 35° E longitude, two centers of production are observed in Elâzığ province in the Eastern and Southeastern Anatolia line, and in Muğla province in the Southwestern Anatolian side (Figure 1, 2, 4). When this distinction is considered, of the 22 provinces with a production share of 1% or more, the shares of cultivation in Elâzığ-centered production have increased in Elâzığ, Şanlıurfa, Kahramanmaraş, Kayseri, and Gaziantep (Figure 2). In contrast, in Muğla-centered production, the shares of cultivation in Muğla, Burdur, Aydın, Denizli, Isparta, and Antalya have decreased. Considering that Elazığ's production share changed from 9.72% to 24.81% and Muğla's from 17.43% to 14.77% between 2015 and 2024, Elâzığ rose to the top with its 2024 production, while Muğla fell to second place (TSI, 2025), indicating that the production centre has shifted from west to east. This change in Türkiye's inland rainbow trout production may be related to socio-economic factors such as investment policies, incentive programs, and infrastructure development (Çöteli, 2023; 2024).

Table 1. Türkiye's trout aquaculture volume in the last 10 years (tonnes) (TSI, 2025).

Year	R. trout	YoY	*Salmo* sp.	YoY	∑	YoY	%	Total
				Inland water				
2015	100,411		755		101,166		93.64	108,038
2016	99,712	-0.70%	1,473	95.10%	101,185	0.02%	94.65	106,901
2017	101,761	2.05%	1,944	31.98%	103,705	2.49%	94.57	109,657
2018	103,192	1.41%	1,695	-12.81%	104,887	1.14%	91.61	114,497
2019	113,678	10.16%	2,375	40.12%	116,053	10.65%	92.29	125,745
2020	126,101	10.93%	1,804	-24.04%	127,905	10.21%	87.25	146,594
2021	134,174	6.40%	1,558	-13.64%	135,732	6.12%	81.14	167,286
2022	144,347	7.58%	1,302	-16.43%	145,649	7.31%	76.21	191,103
2023	154,991	7.37%	1,440	10.60%	156,431	7.40%	70.31	222,486
2024	169,473	9.34%	1,432	-0.56%	170,905	9.25%	73.80	231,591
∑/Average	1,247,840	6.06%*	15,778	12.26%*	1,263,618	6.07%*	82.92	1,523,898
				Marine areas (Black Sea)				
2015	6,187		685		6,872		6.36	108,038
2016	4,643	-24.96%	1,073	56.64%	5,716	-16.82%	5.35	106,901
2017	4,972	7.09%	980	-8.67%	5,952	4.13%	5.43	109,657
2018	9,235	85.74%	375	-61.73%	9,610	61.46%	8.39	114,497
2019	9,411	1.91%	281	-25.07%	9,692	0.85%	7.71	125,745
2020	18,182	93.20%	507	80.43%	18,689	92.83%	12.75	146,594
2021	31,509	73.30%	45	-91.12%	31,554	68.84%	18.86	167,286
2022	45,454	44.26%			45,454	44.05%	23.79	191,103
2023	66,055	45.32%			66,055	45.32%	29.69	222,486
2024	60,686	-8.13%			60,686	-8.13%	26.20	231,591
∑/Average	256,334	35.30%*	3,946	-8.25%*	260,280	32.50%*	17.08	1,523,898

Total production share: 98.71% rainbow trout & 1.29% *Salmo* sp.
*AAGR: Average Annual Growth Rate. R. trout: Rainbow trout, YoY: Year-over-Year.

Based on the latest data from 2024, inland rainbow trout farming in two centers can be divided into four categories according to the production shares of the provinces (Table 2). The production shares of the provinces in categories 1 (Elazığ and Muğla), 2 (Kahramanmaraş, Şanlıurfa, Gaziantep, Kayseri, Samsun, Malatya, Tunceli, Artvin), and 3 (Kırşehir, Tokat, Burdur, Adana, Aydın, Sivas, Gümüşhane, Van, Denizli, Erzurum, Antalya, and Isparta) were 39.58%, 35.31%, and 16.75%, respectively. However, the provinces that account for 74.89% of production in the first two categories are the regions that bear the brunt of rainbow trout farming in inland waters. Total production shares of the 53 provinces in category 4, which has a share of less than 1%, was 8.36%. Kahramanmaraş stands out with a 4.7-fold increase in production, while Isparta stands out with a 55.34% decrease (Table 2).

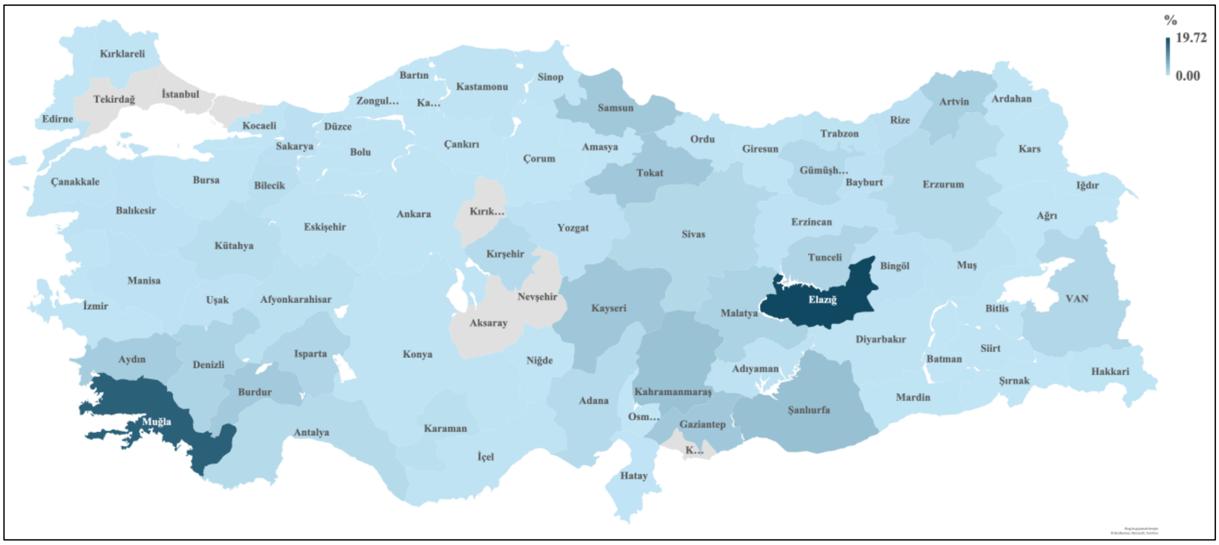


Figure 1. Percentage distribution of Türkiye's total inland water rainbow trout production of 1,247,840 tonnes between 2015 and 2024, by province (TSI, 2025). Zongul.: Zonguldak, Kırık.: Kırıkkale, Osm.: Osmaniye, K.: Kilis.

Salmo species, on the other hand, were grown in a more limited geography due to the effect of ecological adaptation. During this period, the production of *Salmo* sp. (Figure 3) has taken place in the provinces of Artvin, Gümüşhane, Rize, Muş, Van, Kahramanmaraş, Kırşehir, Erzincan, Bitlis, Trabzon and Bartın. Artvin, Rize, and Van provinces in the Eastern Black Sea and Eastern Anatolia regions have been the provinces with the most intensive production (TSI, 2025). The provinces with the highest production were Gümüşhane with 66.23% in 2015 and Artvin with 47.56% in 2024 (Figure 3). While continuous production was carried out in Rize between 2015 and 2024, Van has had continuous production for the last five years (TSI, 2025). Although *Salmo* sp. production occurs in lower quantities, its AAGR is higher than that of rainbow trout, suggesting that this species needs more support for farming in suitable ecological regions.

Between 1950 and 2024, rainbow trout farming was carried out in 87 countries (FAO, 2026). To date, the number of countries farming in freshwater, marine, and brackish water environments worldwide is 85, 23, and 4, respectively. In 2024, Norway, Chile, Türkiye, and Russia accounted for 32.11%, 21.35%, 20.33%, and 16.64% of marine production, respectively, totaling 90.42% (FAO, 2026). In freshwater production, Iran (30.00%) and Türkiye (19.19%) are the dominant countries; the Russian Federation ranks third with 6.34% (FAO, 2026). As shown in Table 1, Figure 1, 2, and 3, and according to world production values for 2024 (FAO, 2026), Türkiye is among the leading countries in rainbow trout farming. Consequently, of the 1,181,668.39 tonnes of rainbow trout produced globally in 2024, 74.73% were farmed in freshwater, and 25.27% were farmed in marine areas (FAO, 2026). The increase in rainbow trout production in Türkiye (Table 1, Figure 2, 3) can be explained by the results emphasizing the rapid development of the Turkish aquaculture sector within the framework of both facility investments and technological advancements (Çöteli, 2023; 2024), as well as rising food demand, export opportunities, investment incentives, and rural development policies (Çöteli, 2023). The increasing trout production in marine areas (Table 1) is due to the sector's shift towards marine fisheries and its recognition of the potential in this area. This result, rainbow trout farming in the Black Sea, particularly for export, is consistent with reports by Baki (2019) and Massa et al. (2021) indicating greater growth. Furthermore, the reaching the production capacity limits of inland water resources (300,053 tonnes/year project capacity based on inland water resources vs. over 170,000 tonnes of real trout production) also encourages a shift towards marine production (TRAF-GDFA, 2026a, b).

The limited production of *Salmo* species may be related to their distribution or occurrence in specific regions, including species defined as endemic, native, relict, and stenotopic (Baycelebi et al., 2015; Küçük et al., 2022; Turan et al., 2009; 2020). It can be recommended that R&D efforts be increased on topics such as feed production, growth performance, and climate adaptation for these species.

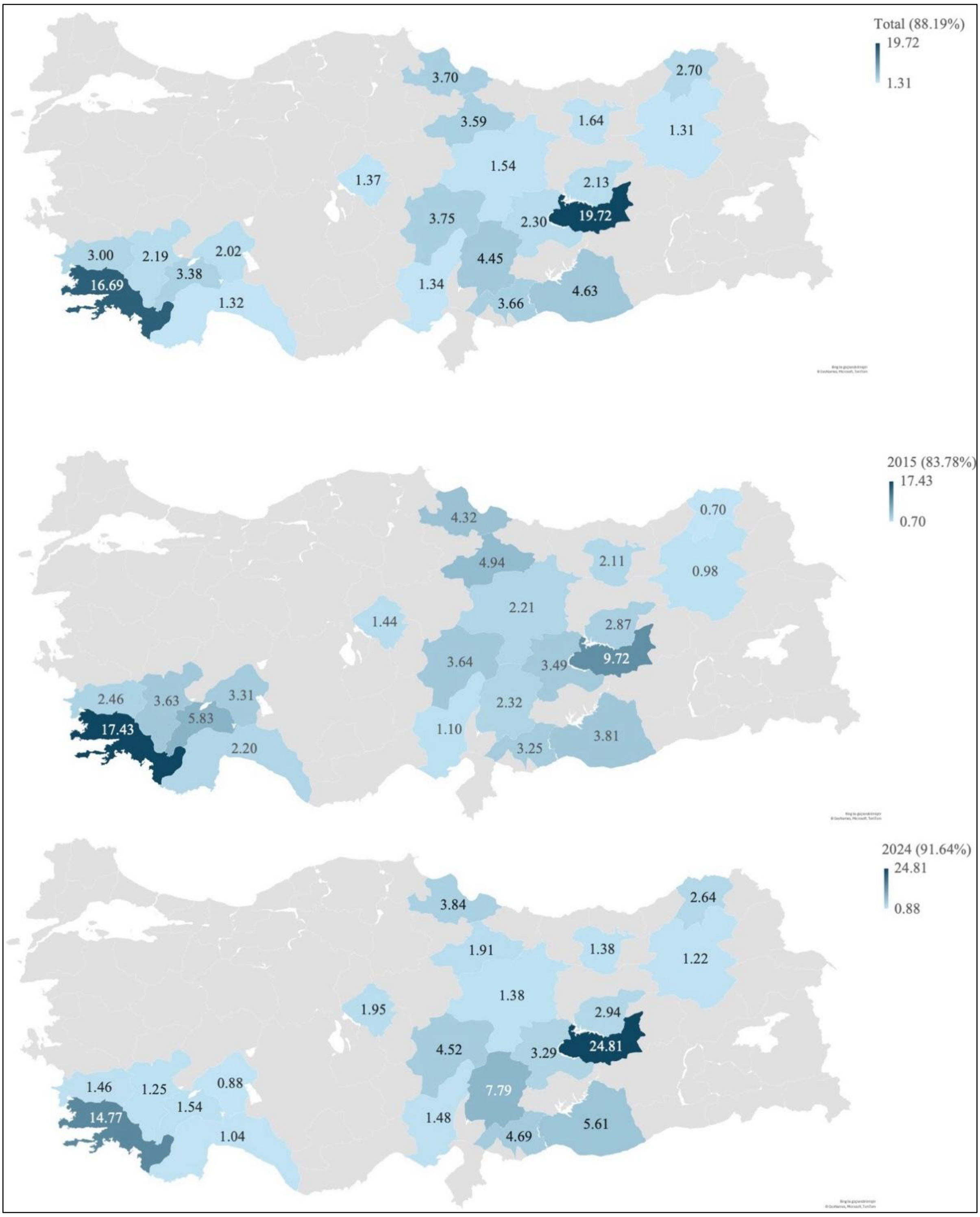


Figure 2. The amount of rainbow trout farmed in Türkiye's inland waters ≥1% (TSI, 2025). The total production of these provinces was 1,100,506 tonnes, with 84,129 tonnes produced in 2015 and 155,305 tonnes in 2024.

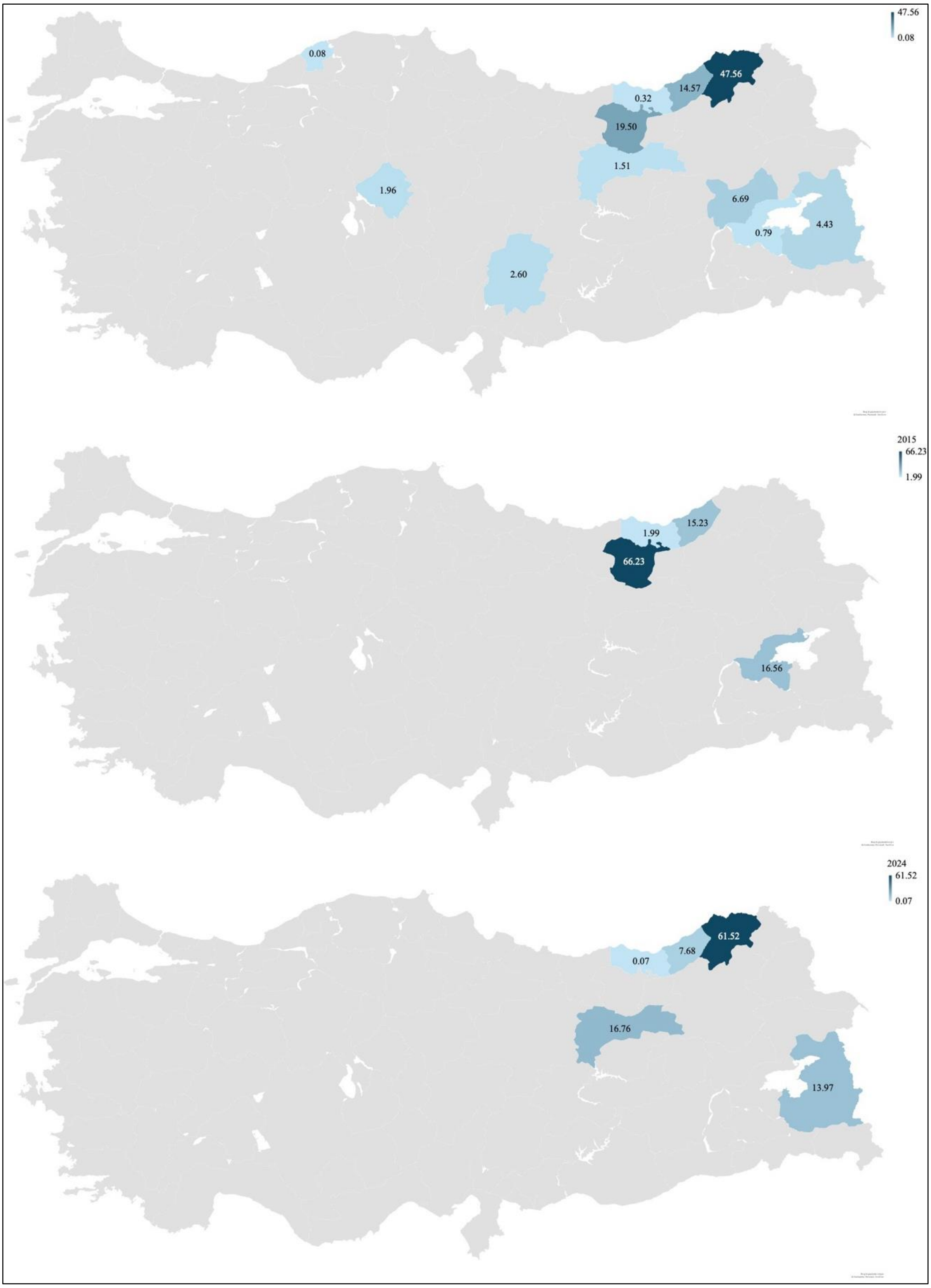
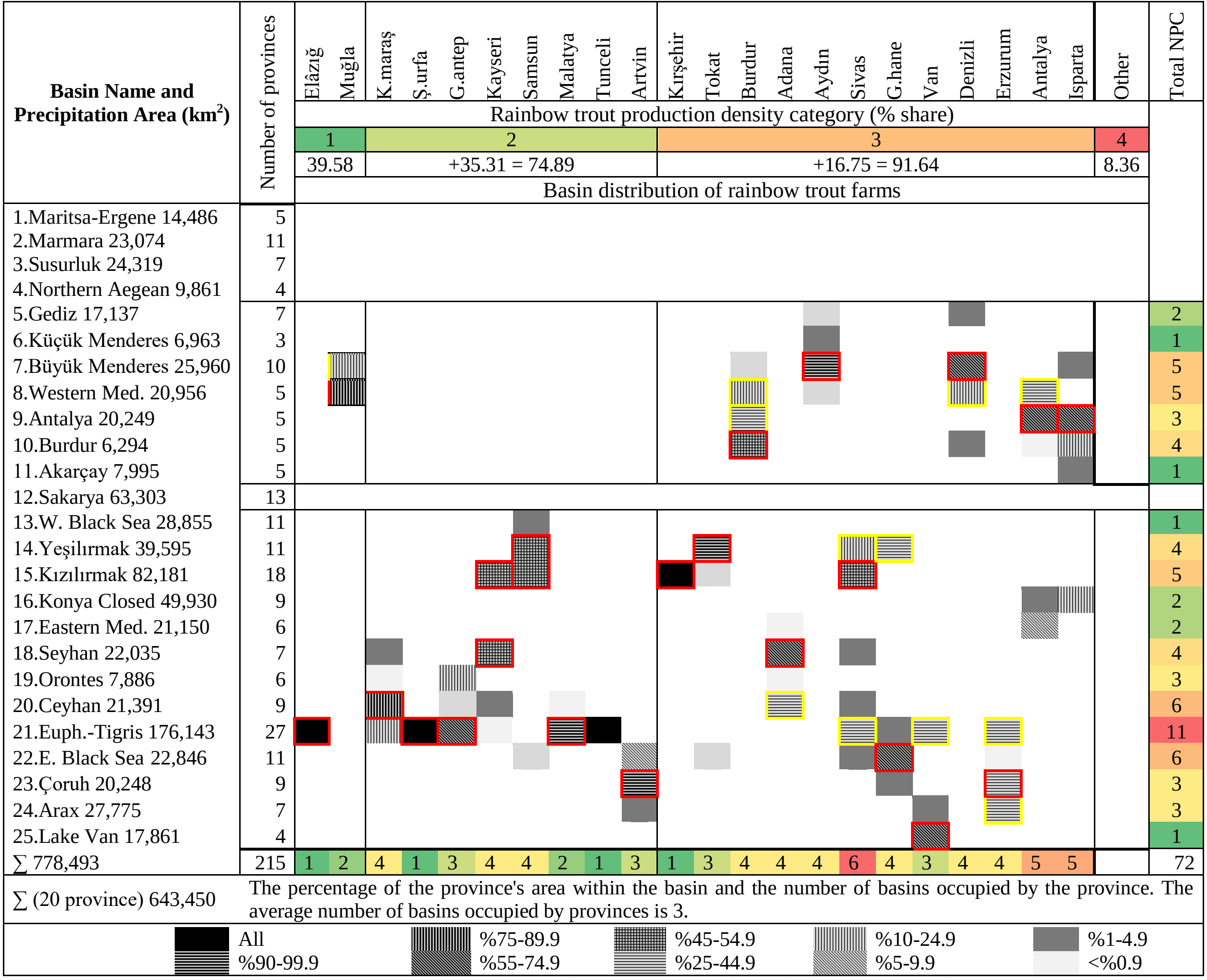


Figure 3. Provinces with *Salmo* sp. production shares in inland water farms (TSI, 2025). Total production was 15,886 tonnes, with 755 tonnes produced in 2015 and 1,432 tonnes produced in 2024.

Table 2. Distribution of provinces with a share of 1% or more in Türkiye's inland rainbow trout farming in 2024, in river basins TSI, 2025; TRAF-GDWM, 2025a, b, c, d, e, f).



Basin Name and Precipitation Area (km^2)	Number of provinces	Elâzığ	Muğla	K.maraş	Ş.urfa	G.antep	Kayseri	Samsun	Malatya	Tunceli	Artvin	Kırşehir	Tokat	Burdur	Adana	Aydın	Sivas	G.hane	Van	Denizli	Erzurum	Antalya	Isparta	Other	Total NPC
		Rainbow trout production density category (% share)																							
		1		2								3												4	
		39.58		+35.31 = 74.89								+16.75 = 91.64												8.36	
		Basin distribution of rainbow trout farms																							
1.Maritsa-Ergene 14,486	5																								
2.Marmara 23,074	11																								
3.Susurluk 24,319	7																								
4.Northern Aegean 9,861	4																								
5.Gediz 17,137	7																								2
6.Küçük Menderes 6,963	3																								1
7.Büyük Menderes 25,960	10																								5
8.Western Med. 20,956	5																								5
9.Antalya 20,249	5																								3
10.Burdur 6,294	5																								4
11.Akarçay 7,995	5																								1
12.Sakarya 63,303	13																								
13.W. Black Sea 28,855	11																								1
14.Yeşilırmak 39,595	11																								4
15.Kızılırmak 82,181	18																								5
16.Konya Closed 49,930	9																								2
17.Eastern Med. 21,150	6																								2
18.Seyhan 22,035	7																								4
19.Orontes 7,886	6																								3
20.Ceyhan 21,391	9																								6
21.Euph.-Tigris 176,143	27																								11
22.E. Black Sea 22,846	11																								6
23.Çoruh 20,248	9																								3
24.Arax 27,775	7																								3
25.Lake Van 17,861	4																								1
∑ 778,493	215	1	2	4	1	3	4	4	2	1	3	1	3	4	4	4	6	4	3	4	4	5	5		72
∑ (20 province) 643,450	The percentage of the province's area within the basin and the number of basins occupied by the province. The average number of basins occupied by provinces is 3.																								

■	All	▥	%75-89.9	▦	%45-54.9	▥	%10-24.9	■	%1-4.9
▤	%90-99.9	▨	%55-74.9	▤	%25-44.9	▨	%5-9.9	□	<%0.9

Total NPC: Total number of provinces in category. K.maraş: Kahramanmaraş, Ş.urfa: Şanlıurfa, G.antep: Gaziantep, G.hane: Gümüşhane, Western Med.: Western Mediterranean, W. Black Sea: Western Black Sea, Eastern Med.: Eastern Mediterranean, Euph.-Tigris: Euphrates-Tigris, E. Black Sea: Eastern Black Sea. The areas in the basin of a province are given in approximate percentage values using a colour scale. A red frame represents the highest level of impact, while a yellow frame represents the second level. The vertical sum of the provinces' basin coverage and the horizontal sum of the province-to-province shares within the basins are expressed using a colour scale.

3.1.2. Basin-based inland rainbow trout farming

In Türkiye, rainbow trout farming in inland waters was concentrated in 20 out of 25 river basins in 2024. The total surface area of these 20 basins where intensive production takes place is 643,450 km², accounting for 91.64% of the production (Table 2). While rainbow trout production per km² in the 20 river basins was 130.75 kg in 2015, this value increased to 241.36 kg in 2024 (Table 1, 2). In the ten-year total production, 1,710.32 kg of rainbow trout were farmed per km² in the 20 river basins. According to Table 2, the production activities of many provinces are affected by more than one river basin. Elâzığ is located entirely within the Euphrates-Tigris (Fırat-Dicle) Basin and had a high production density. Muğla, largely located in the Western Mediterranean (Batı Akdeniz) Basin, is another province with a low basin distribution and intensive production. Among the provinces with a low basin distribution, Şanlıurfa and Tunceli are located entirely within the Euphrates-Tigris Basin, while Malatya is mostly within the Euphrates-Tigris Basin. These provinces have a secondary level of production. Kırşehir, located entirely within the Kızılırmak Basin, has a tertiary level of production. Provinces with this low basin distribution accounted for 53.37% of total production, while Elâzığ, Şanlıurfa, Tunceli, and Malatya, located within the Euphrates-Tigris Basin, had a 36.65% share (Table 2, Figure 2).

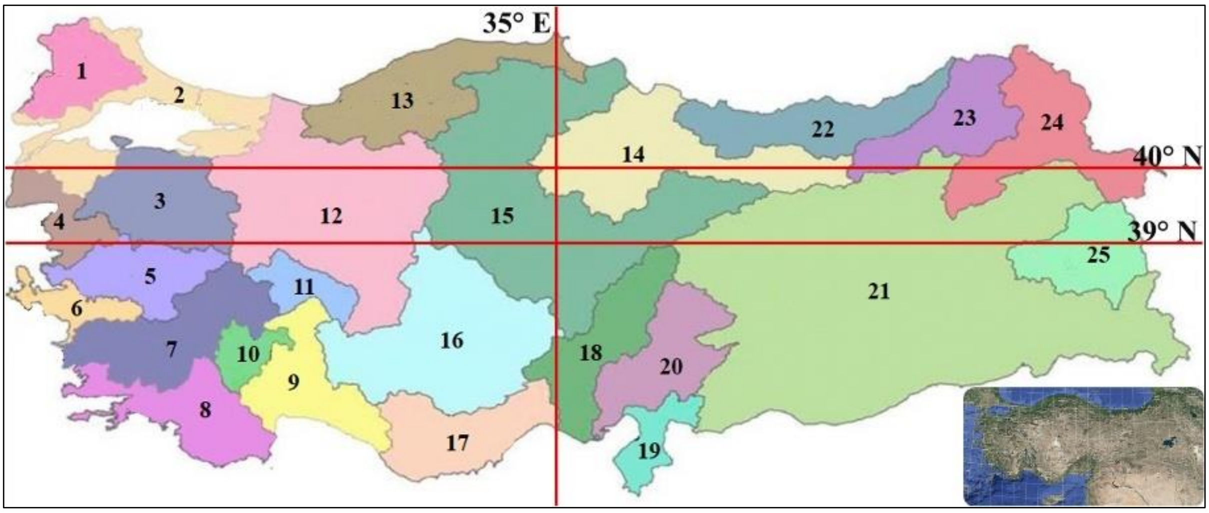


Figure 4. Türkiye's River Basins.1: Maritsa-Ergene, 2: Marmara, 3: Susurluk, 4: Northern Aegean, 5: Gediz, 6: Küçük Menderes, 7: Büyük Menderes, 8: Western Mediterranean, 9: Antalya, 10: Burdur, 11: Akarçay, 12: Sakarya, 13: Western Black Sea, 14: Yeşilırmak, 15: Kızılırmak, 16: Konya Closed, 17: Eastern Mediterranean, 18: Seyhan, 19: Orontes, 20: Ceyhan, 21: Euphrates-Tigris, 22: Eastern Black Sea, 23: Çoruh, 24: Arax, 25: Lake Van (TRAF, 2014). Türkiye's geographical location (Google Earth, August 2025).

Gaziantep (mostly Euphrates-Tigris) and Artvin (mostly Çoruh), which have a medium (3) basin distribution, have a second-degree production intensity (Table 2). Kahramanmaraş, Kayseri and Samsun, which have a second-degree production intensity, are provinces with a high (4) basin distribution (Table 2; Figure 2). These provinces are divided among different basins and have a share of 16.14% in total production in 2024. On the other hand, the share of Gaziantep and Artvin, which have a medium distribution, in total production was 7.33%. While Gaziantep and Artvin, where second-degree intensive production was carried out with a total farming share of 7.33% in 2024, have a medium basin distribution, the share of Kahramanmaraş, Kayseri and Samsun, which have a high basin distribution, was 16.14% (Table 2; Figure 2). The 12 provinces in the third category have a greater basin distribution than the provinces in the first and second categories (Table 2). The production shares of Tokat and Van provinces with medium (3) basin distribution in this category is 3.18% in 2024 (Table 2; Figure 2). The production shares of 9 provinces with high (4 and above) basin distribution is 11.61%. The production shares of Burdur, Adana, Aydın, Gümüşhane, Denizli and Erzurum provinces located in 4 basins is 8.31%. The production shares of Antalya and Isparta provinces, which are located in five basins, is 1.92%. The production share of Sivas province, which has the largest basin (6) distribution in Türkiye, is 1.38% (Table 2; Figure 2).

Findings indicate that rainbow trout farming in Türkiye is not evenly distributed spatially (Table 2; Figure 2). Provinces such as Elâzığ and Muğla, in particular, are leaders in production thanks to both favorable hydrological conditions and well-developed aquaculture infrastructure. While the hydrological potential of the Euphrates-Tigris Basin supports production, small- and medium-scale production is more pronounced in the Western Anatolian Basins. The increase in the production shares of provinces with 1% or more production (83.78% vs. 91.64%) necessitates regional and basin-level planning (Table 2; Figure 2). The dominance of provinces with low basin distribution in production suggests that production is spatially limited but concentrated. Conversely, provinces with high basin distribution offer greater potential for geographical diversity and can play a strategic role in ensuring the sustainability of the sector. The highest production occurs in the Euphrates-Tigris, Western Mediterranean, and Büyük Menderes Basins. Elâzığ, located in the Euphrates-Tigris Basin, where production is highest, and with 10 other provinces in the basin, the Euphrates-Tigris Basin is a strategic production center (Table 2; Figure 2).

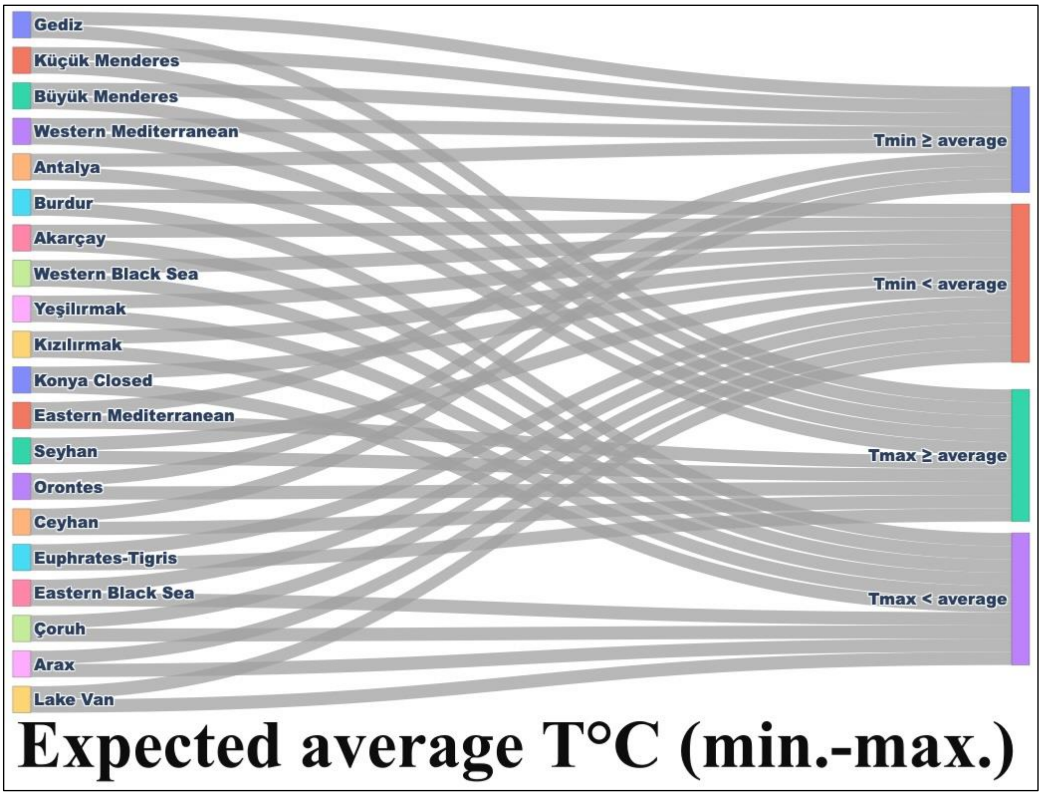


Figure 5. Temperature changes in the basins in 2071-2100 compared to the reference year 1971-2000. The decimal part has been rounded. It is structured according to Supplementary Table 2 (TRAF-GDWM, 2020).

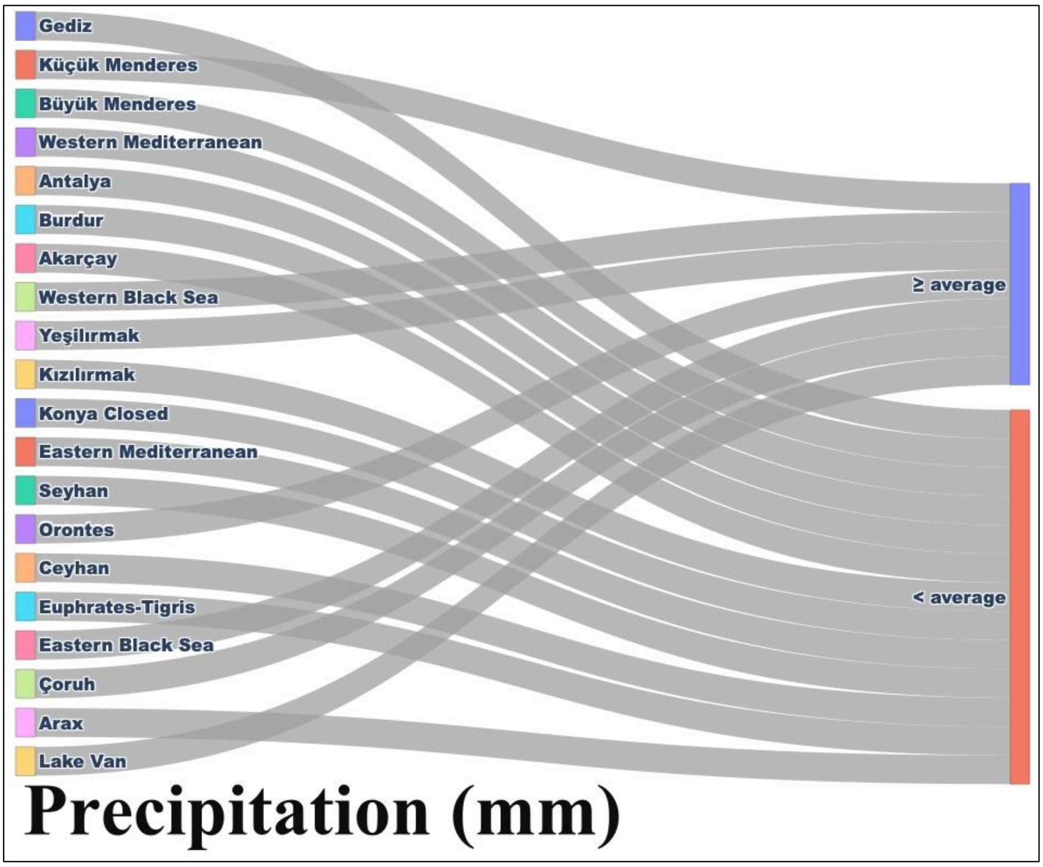


Figure 6. Precipitation changes in the basins in 2071-2100 compared to the reference year 1971-2000. It is structured according to Supplementary Table 2 (TRAF-GDWM, 2020).

Muğla, with the second-highest share in production, is located within the Büyük Menderes and Western Mediterranean Basins, with a total of 10 provinces distributed within these two basins. Along with Kahramanmaraş, which has the third highest share in aquaculture, the Ceyhan and Seyhan Basins, representing 10 provinces, are also strategically located for rainbow trout production in inland waters. In the Black Sea Region, the provinces of Samsun, Artvin, Tokat, and Gümüşhane demonstrate the strategic importance of the Kızılırmak, Yeşilırmak, and Eastern Black Sea Basins (Table 2; Figure 2). In conclusion, Türkiye has two production centers located below latitude 39°-40° N and according to longitude 35° E. Given this geographical location, Elâzığ province is located in the Euphrates-Tigris Basin, and Muğla province is located in the Büyük Menderes and Western Mediterranean Basins, and therefore, considering these basins as special status will be critically important for inland rainbow trout aquaculture in Türkiye (Table 2; Figure 2, 4).

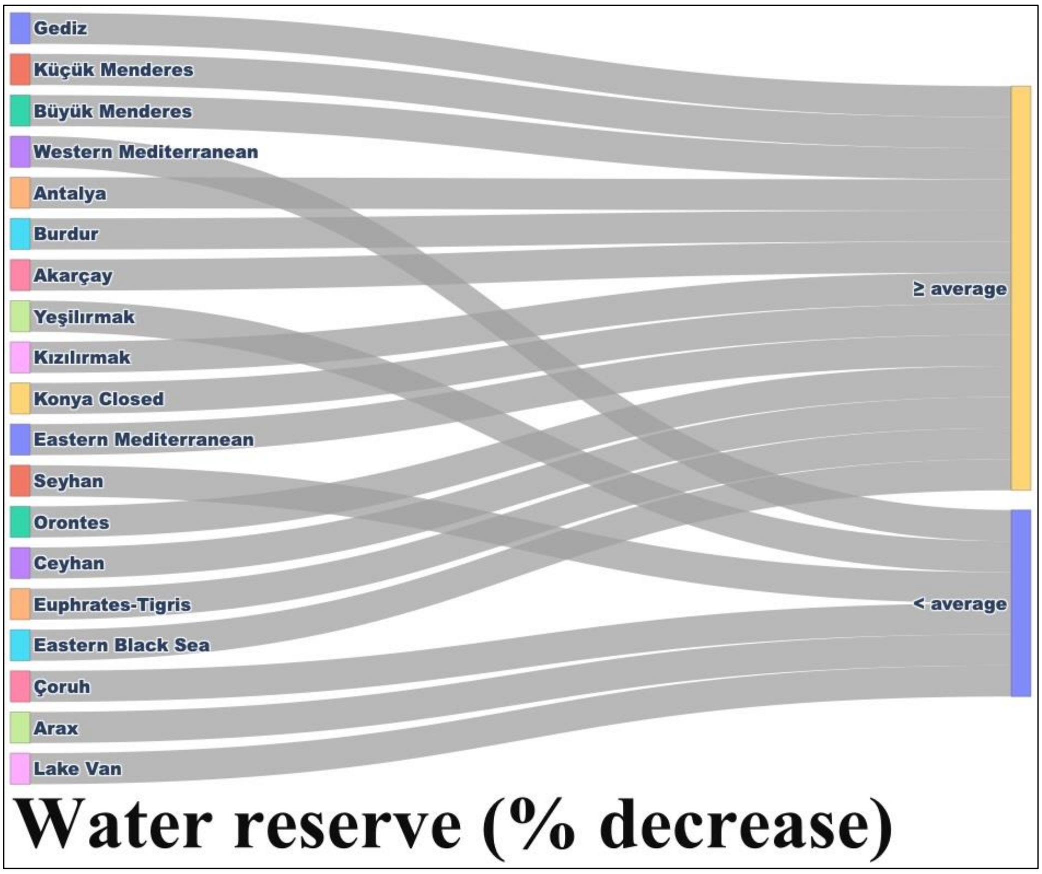


Figure 7. Water reserve changes in the basins in 2041/2071-2100 compared to the reference year 1971-2000. It is structured according to Supplementary Table 2 (TRAF-GDWM, 2020).

3.2. Basin-Based Risk Assessment of Climate and Hydrological Changes

According to the climate projection based on reference years, average temperatures across Türkiye are expected to increase by 1.8-5.1°C by 2100, while precipitation is expected to decrease by 11.9%, water reserves by 55%, and groundwater reserves by 15% (Supplementary Table 2). The average atmospheric temperature between 1970 and 2024 was observed as 13.3°C (Figure 9). According to measurements in the first 30 years, the temperature was 12.8°C, while it reached 14.0°C in the first 25 years of the second 30 years. Temperature increases in the second 30-year period have currently increased by 1.2°C. This temperature change observed in meteorological data indicates that it is approaching the minimum temperature change of 1.8°C expected after 2070 (Supplementary Table 2). The maximum temperature increases in the future projection are expected to be more effective in the Gediz, Küçük and Büyük Menderes, Western Mediterranean, Antalya, Eastern Mediterranean (Doğu Akdeniz), Seyhan, Orontes (Asi), Ceyhan, Euphrates-Tigris Basins (Figure 5). The precipitation observed after 2020

(Figure 6) reflects the likely precipitation after 2070 (Supplementary Table 2). Precipitation is expected to decrease by 11.9% by 2100, falling to 532.9 mm. This decreasing trend is most pronounced in the Gediz, Büyük Menderes, Burdur, Akarçay, Kızılırmak, Konya Closed (Kapalı), Seyhan, Euphrates-Tigris, and Arax (Aras) Basins, which remain below the mean value of the reference years. The number of these basins is projected to increase to 13 (Gediz, Büyük Menderes, Western Mediterranean, Antalya, Burdur, Akarçay, Kızılırmak, Konya Closed, Eastern Mediterranean, Seyhan, Ceyhan, Euphrates-Tigris, and Arax) after 2070 (Figure 6). The Euphrates-Tigris Basin is the outlier with the highest reserves with a share of 29.1%, while the Western Mediterranean (0.5%) has the lowest reserves. Average annual water reserves are expected to decrease from 7,858.4 million m³ to 3,536.28 million m³ during the 2071-2100 period. The Euphrates-Tigris Basin, which includes Elâzığ, will experience the highest reserve loss with 34,300.20 m³/year (Supplementary Table 2). In 13 basins where rainbow trout production in inland waters is 1% or more, water reserves are projected to decrease at an average or higher rate (Figure 7). The Burdur (81.68%), Akarçay (80.38%), Konya Closed (68.74%), Büyük Menderes (61.57%), and Gediz (57.68%) basins are expected to experience the greatest proportional water deficit (the ratio of water deficit to water reserve; Supplementary Table 2). It is likely that there will be decreases in groundwater reserves exceeding the average values of the reference years in the Büyük Menderes, Western Mediterranean, Antalya, Akarçay, Western Black Sea (Batı Karadeniz), Kızılırmak, Konya Closed and Euphrates-Tigris Basins, which constitute 1% or more of production (Figure 8).

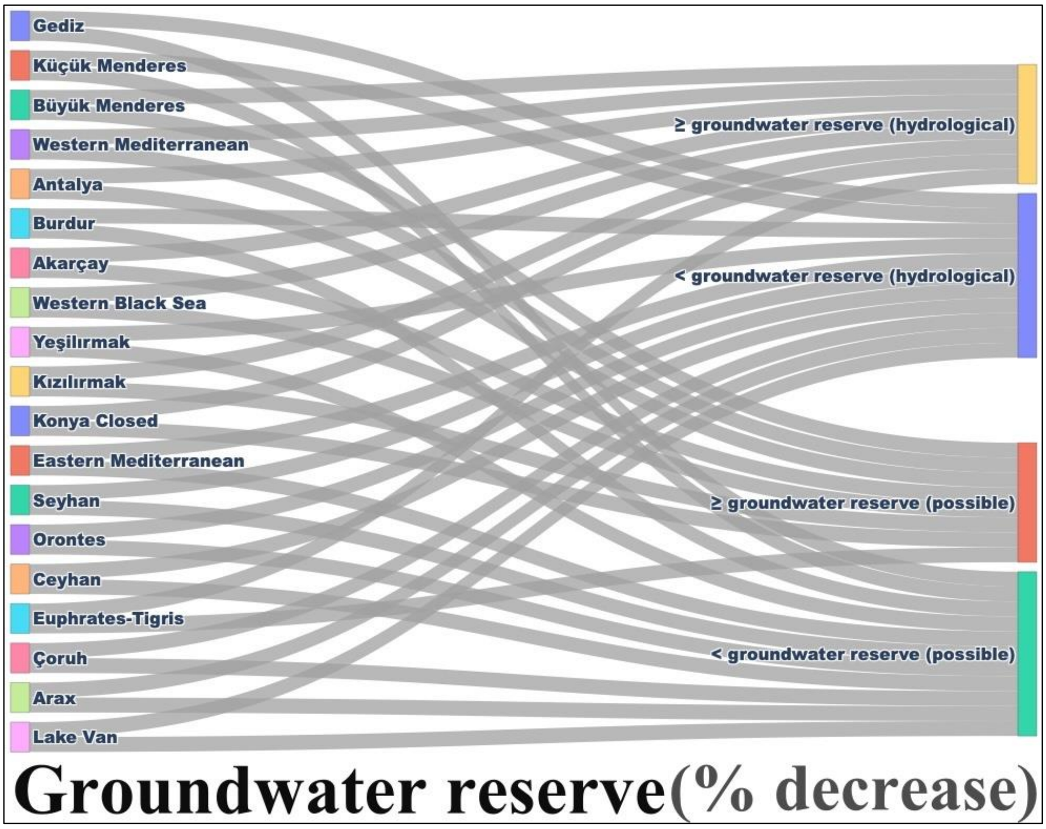


Figure 8. Groundwater reserve changes in the basins in 2071-2100. It is structured according to Supplementary Table 2 (TRAF-GDWM, 2020).

Table 3 presents the basin-based risk assessment of provinces with a share of 1% or more in rainbow trout production according to the future water status of Turkish River Basins. The Euphrates-Tigris Basin is assessed in the highest risk group due to its leadership in Turkish rainbow trout production. It demonstrates different changes from Türkiye's future average values in terms of temperature, precipitation, water reserves, water deficit, and groundwater reserves (Figure 5, 6, 7, 8). A total of 12 basins from the Euphrates-Tigris Basin to the Burdur

Basin are in the high-risk group (Table 3). The total number of basins, including those with medium risk status, is 14. Considering the surface areas of the provinces located within the basin areas, Artvin is the only province in the low and potential risk group in terms of climate change effects (Table 3; Figure 2, 4). Low and potential risk group basins such as the Arax, Western Black Sea, Lake Van (Van Gölü), Çoruh, the Eastern Black Sea and Yeşilırmak have low shares of current production, limited water losses, and can become production centers that are more resilient to climate conditions in the future (Table 3; Figure 2, 4). Production investments in the Western Black Sea and Arax Basins, especially those located above latitudes 39°-40° N, can be strategic. Considering the surface areas of the provinces located in these basins, Samsun, Tokat, Gümüşhane, Van, and Erzurum are in a more advantageous position compared to other provinces in terms of risk assessment. Production in the provinces of Elâzığ, Muğla, Kahramanmaraş, Kayseri, Burdur, Adana, Aydın, Sivas, Denizli, Antalya, and Isparta, which are located in high and moderate risk basins according to their basin areas, is expected to be significantly but at different rates affected by the effects of climate change (Table 3; Figure 2, 4).

Türkiye's rainbow trout production geography is at risk according to future climate change projections (Table 3). Current production intensity is largely concentrated in basins expected to experience high water loss and water stress (Table 3; Figure 2, 4). Surface and groundwater reserve losses pose serious risks to the future of the sector and threaten its sustainability. Temperature increases (especially in basins above 5°C) can negatively impact the physiology of coldwater fish such as rainbow trout. Therefore, thermal stress factors should be monitored, and production should be conducted with temperature-tolerant species. In provinces with intensive trout production (e.g., Elâzığ and Muğla), basin-based water transportation and use plans should be reviewed. New plans should be shaped with production models compatible with climate change and policies that take regional differences into account. Mechanization to increase the oxygen content of water enabling fish production at low water flow should be integrated with RAS and wastewater recycling systems. Production capacity should be limited, and sustainable water allocation plans should be developed. Priority areas for new investments can be identified. Monitoring studies should be conducted for potential development projects in provinces where production has not yet become widespread.

According to Maulu et al. (2021), climate change effects such as temperature increases, precipitation irregularities, droughts, and floods, which degrade water quality, are among the significant risks threatening the production and sustainability of aquaculture. This situation also poses threats to inland rainbow trout farming in Türkiye (Table 3, Figure 5, 6, 7, 8). Türkiye's areal precipitation in 2024 was 537.2 mm, and its average annual areal precipitation (1991-2020 normals) was 573.4 mm, decreasing by 6.3% and 16.3% compared to normal and the previous year, respectively (TSMS, 2025b). The same report reported that annual precipitation across Türkiye decreased based on the number of years in which precipitation was below normal in 2020 and thereafter. The decreasing trend in precipitation in this report is similar to the decreasing trend in precipitation across Türkiye shown in Figure 9. The same report reported that basin-based areal precipitation for 2024 decreased compared to normal in 19 basins except the Eastern Mediterranean, Euphrates-Tigris, Eastern Black Sea, Çoruh, Arax, and Lake Van. This year-based assessment when associated with the expectations for precipitation change in Figure 6, is important in terms of the necessity of monitoring the basin risk assessments given in Table 3.

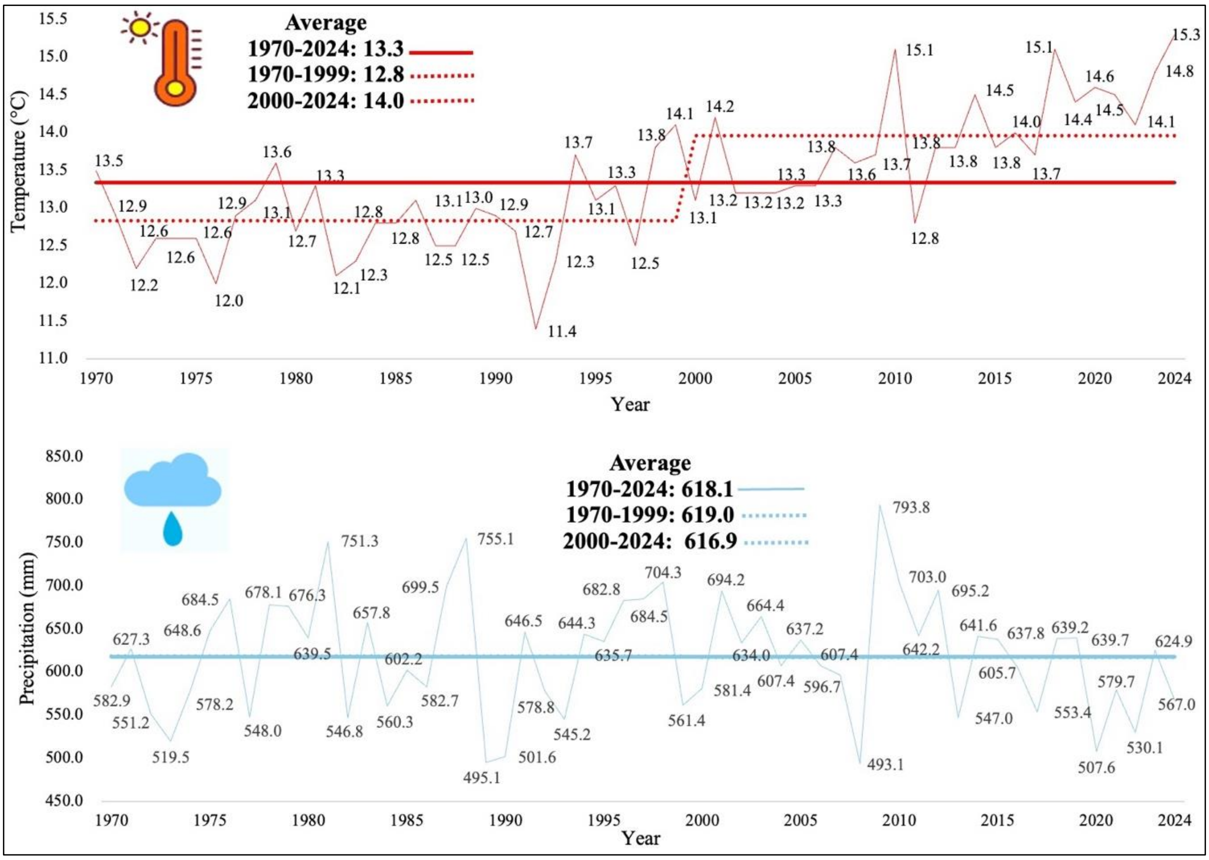


Figure 9. Changes in temperature and precipitation in Türkiye (TSMS, 2025a).

Table 3. Critical basins and risk assessment based on water status and 2024 inland rainbow trout farming values*

Basin	Score	Production	Climatic assessment	Risk
Euphrates-Tigris	4	Very high	Although water potential appears high, reserves are in decline. A temperature rise (~ 6.0°C) could make difficult production.	🔴
Büyük Menderes	4	High	Basins are under high stress due to water loss and temperature increases. Reserve losses are high. Water management and adaptive production are essential.	🔴
Kızılırmak	3.5	Medium		🔴
Ceyhan	3	Medium		🔴
Orontes	2	Medium		🔴
Antalya	4	Low		🔴
Konya Closed	3.5	Low		🔴
Gediz	3	Low		🔴
Akarçay	3	Low		🔴
Eastern Mediterranean	3	Low		🔴
Küçük Menderes	2	Low		🔴
Burdur	2.5	Low		🔴
Western Mediterranean	2.5	Low	Rising basin temperatures could affect rainbow trout production. Long-term reserve loss could pose a problem.	🟠
Seyhan	2	Low		🟠
Arax	1.5	Low	The least affected basins. Relatively less water loss. They have relative advantages in terms of water resources. Precipitation may still be sufficient.	🟢
Eastern Black Sea	1	Low		🟢
Lake Van	0.5	Low		🟢
Çoruh	0.5	Low		🟢
Western Black Sea	0.5	Low		🟢
Yeşilırmak	/	Low		🟢

High Medium Low&Potential 🔴 🟠 🟢🟢

*Score are arranged according to Figure 5, 6, 7, 8 (TRAF-GDWM, 2020). The loss of water reserves is critical. In production, inland rainbow trout farming in Table 2 was taken into account.

Associated with the decreasing trend in precipitation, Türkiye's semiarid steppe and Mediterranean climate zones are expanding, while its cold summer climate zones are contracting (Türkeş and Yurtseven, 2025). Similarly, Yılmaz and Çiçek (2019) stated that the expansion of Türkiye's dry summer and warm-temperate climates is expected to be accompanied by the contraction of its cold climate zones. As an indicator of climate change, these temperature increases will be 1-2 °C greater in the Eastern and Southeastern regions, and while a general decrease in precipitation is expected, an increase is projected only along the Black Sea coast (TRAF, 2023). This regional difference in temperature increases and the decreasing trend in precipitation are consistent with Table 3. The basin-based relationship between regional temperature and precipitation changes in Table 3 demonstrates the basin-based accuracy of the risk assessment. It has also been reported that rising temperatures will increase dry periods, reaching 140-160 days in Southeastern Anatolia and 30-70 days along the Black Sea coast (TRAF, 2023). Türkiye's 12-month drought map covering the period September 2024-August 2025 (TSMS, 2025c) also supports these reports. A large portion of the basins below 39°- 40° N latitude, which are expected to be more affected by climate change (Figure 4, Table 3), aligns with these reports and is classified as severe to moderate drought in the TSMS (2025c) report.

In addition to these climate change reports, it has been reported that Türkiye's water budget is at risk of falling from an annual surplus of 14.6 km^3 to a deficit of 57.3 km^3 in the 2071-2100 scenario, and that the risk of water deficit in river basins will reach 60-72% by 2100 (Pilevneli et al., 2023). This report, along with the values in Figure 5, 6, 7, 8 and Table 3, highlights the importance of basin-based water management risk assessment. This risk profile indicates that, as is the case globally, the vulnerability and sensitivity of freshwater aquaculture systems in Türkiye to climate change is high (Handisyde al., 2017). According to the same report, Türkiye's freshwater system resources are moderately sensitive to climate change, and the adaptation capacity of its freshwater and marine systems is below average. These findings, when considered together with the temperature and precipitation changes shown in Figure 9 and the temperature, precipitation and water availability presented in Figure 5, 6, 7, 8, indicate that there is a high probability of a decrease in Türkiye's water reserves in the future. Consequently, the impacts of climate change on water resources are expected to increase the pressure on inland rainbow trout aquaculture. Given the projected consequences of climate change, the development of basin-specific risk assessment scenarios, as shown in Table 3, is vital for effective aquaculture planning. Regarding climate change, Türkiye is among the countries experiencing water stress in terms of annual water consumption per capita (TRAF, 2023). Similarly, studies highlighting the increasing water stress in Türkiye's River Basins (García-Valiñas et al., 2010 as cited in Henrichs et al., 2007; Meißner, 2021 as cited in Gassert et al., 2013), the projected increase in water scarcity affecting 40% of the country (FAO, 2017), and the risk of desertification in Turkish territory (Uzuner and Dengiz, 2020) highlight the need for basin-based risk assessments. These studies reinforce the necessity of planning inland aquaculture activities at the basin scale, considering their projected impacts on water resources based on potential water availability as indicated in Table 3. Furthermore, all these reports will contribute to questioning the sustainability of livelihoods in terms of production gradations (from high to low production), as in Table 3, which considers changes in basins due to declining water reserves. In light of these approaches, considering the regional distribution of production capacity classes in rainbow trout farming in Türkiye, as well as hatchery and egg production (Çakmak et al., 2024), the enterprises in a total of 14 basins, 12 of which are high-risk and 2 of which are low-risk, are located in high and medium-risk basins. Therefore, the sustainability of rainbow trout farming in inland waters requires a basin-based risk assessment, as outlined in Table 3, adhering to quantitative and methodological approaches for efficient water use, as emphasized in the Mohtar and Farez (2022) report. However, for such studies to yield results, the relationship between the adaptive capacities of producers in different regions and the sustainability of the sector must be targeted (Maulu et al., 2021).

It was reported by FAO (2017) that agricultural production will increase by 60% by 2050, that the pressure on water and other natural resources will increase due to increasing food demand, that more than 40% of the world's population will live in river basins experiencing serious water stress, and that intersectoral tensions and environmental pressures will increase. Pilevneli et al. (2023) also reported that the Maritsa-Ergene, Marmara, Susurluk, Northern Aegean, Gediz, Küçük Menderes, Büyük Menderes, Burdur, Akarçay, Sakarya, Kızılırmak, Konya Closed, Orontes, Ceyhan and Euphrates-Tigris Basins in Türkiye will face water scarcity in the short, medium, and long term. In addition to these reports, among the recommendations for adaptation to climate change, a transition to basin-scale planning is recommended in assessments related to water resources management (TREUC-CD, 2024). According to the report Pilevneli et al. (2023), the basins identified as being at risk of water scarcity are the same as the basins in the high-risk groups listed in Table 3. The basin-based risk assessment in Table 3 meets the basin-scale planning recommendations of the TREUC-CD (2024) report. The study results are consistent with assessments of potential climate risks and require basin-based risk and future planning for inland trout aquaculture.

CONCLUSION

While production nationwide is showing a steady increase, the concentration of production in certain provinces, as well as the emergence of a new production centre within the Euphrates-Tigris Basin in the centre of Elâzığ Province, indicates a new specialisation. Climate change projections indicate that the current production geography and intensity are at risk. The concentration of inland trout farming in basins with a high risk of water loss should be a cause for concern for the sector's future. Water management policies must be restructured to enable aquaculture to adapt to these pressures of climate change through strategic changes. Planning should be based on basin-based dynamic water reserve estimates and long-term climate scenarios. Urgent adaptation policies and planning measures can be proposed for the 39°-40° N latitude and basins below this latitude, from Western to Eastern Anatolia. Demand-side strategies (water conservation, drip irrigation, graywater use) should be prioritized over supply-side policies (dams, transfers). Investments should be directed towards mechanisation models such as oxygen generators that provide low water consumption, high water quality and efficiency, as well as aquaculture systems like RAS and In-Pond Raceway Systems. Aquaculture should be integrated with wastewater recycling systems. Low-risk basins such as the Eastern and Western Black Sea, Arax, Lake Van, Çoruh, and Yeşilırmak, can be identified as priority investment areas, and potential development projects in these basins can be monitored. Groundwater resources should be protected and their security ensured. These low-risk basins, which account for a small share of current production, could become more climate-resistant production centers in the future due to limited water losses. Climate-resilient species and production systems should be developed, and genetic research should be prioritized. Climate-resilient strategies should be developed. Thermal stress factors should be monitored, and heat-tolerant species may be important for production. Studies on climate-resistant aquaculture genes should be conducted, and research on fish species that can adapt to high temperatures and low water reserves could be important. Türkiye's sustainable fisheries sector plans should be shaped by climate change-compatible production models and policies that take regional differences into account, and climate change adaptation funds should be established.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the author used ChatGPT (GPT-5.3; OpenAI, 2026) to create or adapt Python scripts for Sankey diagrams. After using this tool, the author reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

FUNDING

No financial support was received for the present study.

CONFLICT OF INTEREST

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTION

Fiction, Literature, Methodology, Performing the experiment, Data analysis, Manuscript writing, Supervision: GD. Author approved the final draft.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

REFERENCES

Baki, B. (2019). Aquaculture production in the black sea Turkey. *International Journal of Fisheries Aquatic Studies*, *7*(4), 1”21-124

Baycelebi, E., Turan, D., & Japoshvili, B. (2015). Fish fauna of Coruh River and two first record for Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, *15*(4), 783-794. https://doi.org/10.4194/1303-2712-v15_4_01

Bölük, E., Eskioğlu, O., Çalık, Y., & Yağan, S. (2023). Köppen iklim sınıflandırmasına göre Türkiye iklimi. TC Orman ve Su İşleri Bakanlığı Meteoroloji Genel Müdürlüğü, Araştırma Dairesi Başkanlığı, Klimatoloji Şube Müdürlüğü, Ankara. https://scholar.google.com/scholar?hl=tr&as_sdt=0%2C5&q=KÖPPEN+İKLİM+SINIFLANDIRMASINA+GÖRE+TÜRKİYE+İKLİMİ&btnG=

Çakmak, E., Özel, O. T., Batır, E., & Evin, D. (2024). Gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) endüstrisinde yeni bir yaklaşım:" Türk Somonu" üretim ve pazarlama eğilimleri. *Ege Journal of Fisheries and Aquatic Sciences*, *41*(1), 69-81.

Çelik, P., & Akmermer, B. (2022). Target market selection for the major aquaculture products of Turkey-an evaluation on export markets by hybrid multi-criteria decision-making Approach. *Aquac. Stud.*, *22*(1): AQUAST691. http://doi.org/10.4194/AQUAST69

Çöteli, F. T. (2023). Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü Ürün Raporu Su Ürünleri 2023. Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü. https://arastirma.tarimorman.gov.tr/tepge/Belgeler/PDF%20Ürün%20Raporları/2023%20Ürün%20Raporları/Su%20Ürünleri%20Ürün%20Raporu%202023-373%20TEPGE.pdf

Çöteli, F. T. (2024). Agricultural products market-2024-july. https://arastirma.tarimorman.gov.tr/tepge/Belgeler/PDF%20Tarım%20Ürünleri%20Piyasaları/2024-Temmuz%20Tarım%20Ürünleri%20Raporu/Su%20Ürünleri%20Tarım%20Ürünleri%20Piyasaları%20Raporu%20Temmuz-2024-v5.pdf?utm_source

EEA. (2021). Water resources across Europe - confronting water stress: an updated assessment (Report No. 12/2021). European Environment Agency. https://www.eea.europa.eu/en/analysis/publications/water-resources-across-europe-confronting

FAO (2017). Water for sustainable food and agriculture: A report produced for the G20 Presidency of Germany. https://openknowledge.fao.org/server/api/core/bitstreams/b48cb758-48bc-4dc5-a508-e5a0d61fb365/content

FAO. (2026). Fisheries and aquaculture, statistical query panel, global aquaculture production. https://www.fao.org/fishery/statistics-query/en/aquaculture

García-Valiñas, M. D. L. Á., Martínez-Espiñeira, R., & González-Gómez, F. (2010). Measuring water affordability: A proposal for urban centres in developed countries. *International Journal of Water Resources Development*, *26*(3), 441-458.

Gassert, F., Reig, P., Luo, T., Maddocks, A. (2013). Aqueduct country and river basin rankings: A weighted aggregation of spatially distinct hydrological ındicators; working paper. World Resources Institute. https://search.issuelab.org/resources/17084/17084.pdf

Google Earth. (2025).Türkiye's geographical location. https://earth.google.com/web/@38.29024994,36.32743029,2033.91190567a,1784636.97478563d,35y,-0h,0t,0r/data=CgRCAggBOgMKATBCAggASg0I____________ARAA

Handisyde, N., Telfer, T. C., & Ross, L. G. (2017). Vulnerability of aquaculture-related livelihoods to changing climate at the global scale. *Fish and fisheries*, *18*(3), 466-488.

Henrichs, T., Pirc Velkavrh, A., Veligosh, E., & Zamparutti, T. (2007). The pan-European environment: glimpses into an uncertain future (Report No. 04/2007). European Environment Agency. https://www.eea.europa.eu/en/analysis/publications/eea_report_2007_4/eea_report_2007_4

IPCC, 2018: Annex I: Glossary. In Matthews, J. B . R. (Ed.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (Eds.). (pp. 541-562). Cambridge University Press. https://doi.org/10.1017/9781009157940.008

Knudsen, S. (2025). ‘Turkish salmon’, Norwegian entrepreneurs, and the global salmon value chain. *Marine Policy*, *171*: 106470. https://doi.org/10.1016/j.marpol.2024.106470

Küçük, F., Turan, D., Güçlü, S. S., Kaya, C., & Gülle, İ. (2022). Türkiye İçsularındaki Doğal Alabalıkların Sistematiği ve Zoocoğrafik Özellikleri. In Sevgili H., & Diken, G (Eds.), *6. Ulusal Alabalık Sempozyumu* (pp 23). Isparta Uygulamalı Bilimler Üniversitesi. https://kutuphane.isparta.edu.tr/?mod=e-kitaplar

Massa, F., Aydın, I., Fezzardi, D., Akbulut, B., Atanasoff, A., Beken, A. T., Bekh, V., Buhlak, Y., Burlachenko, I., Can, E., Carboni, S., Caruso, F., Dağtekin, M., Demianenko, K., Deniz, H., Fidan, D., Fourdain, L., Frederiksen, M., Guchmanidze, A., Hamza, H., Harvey, J., Nenciu, M., Nikolov, G., Niţă, V., Özdemir, M.D., Petrova-Pavlova, E., Platon, C., Popescu, G., Rad, F., Seyhaneyildiz Can, Ş., Theodorou, J. A., Thomas, B., Tonachella, N., Tribilustova, E., Yakhontova, I., Yesilsu, A.F., & Yücel-Gier, G. (2021). Black Sea aquaculture: legacy, challenges & future opportunities. *Aquaculture Studies*, *21*, 181-220. https://doi.org/10.4194/2618-6381-v21_4_05

Maulu, S., Hasimuna, O. J., Haambiya, L. H., Monde, C., Musuka, C. G., Makorwa, T. H., Munganga, B. P., Phiri, K. J., & Nsekanabo, J. D. (2021). Climate change effects on aquaculture production: sustainability implications, mitigation, and adaptations. *Frontiers in Sustainable Food Systems*, *5*, 609097. https://doi.org/10.3389/fsufs.2021.609097

Meißner, S. (2021). The impact of metal mining on global water stress and regional carrying capacities-a GIS-based water impact assessment. *Resources*, *10*(12), 120. https://doi.org/10.3390/resources10120120

Mohtar, R. H., & Fares, A. (2022). The future of water for food. *Frontiers in Sustainable Food Systems*, *6*, 880767. https://doi.org/10.3389/fsufs.2022.880767

Pilevneli, T., Capar, G., & Sánchez-Cerdà, C. (2023). Investigation of climate change impacts on agricultural production in Turkey using volumetric water footprint approach. *Sustainable Production and Consumption*, *35*, 605-623. https://doi.org/10.1016/j.spc.2022.12.013

TRAF. (2014). Ulusal havza yönetim stratejisi (2014-2023). Republic of Türkiye Ministry of Agriculture and Forestry. https://www.tarimorman.gov.tr/SYGM/Belgeler/uhys%20belgesi%20(3).pdf

TRAF. (2023). Değişen iklime uyum çerçevesinde su verimliliği stratejisi belgesi ve eylem plani (2023-2024). Republic of Türkiye Ministry of Agriculture and Forestry. https://www.tarimorman.gov.tr/Duyuru/1819/Degisen-Iklime-Uyum-Cercevesinde-SuVerimliligi-Strateji-Belgesi-Ve-Eylem-Plani-_2023-2033_-Cumhurbaskanligi-GenelgesiYayimlandi

TRAF-GDFA. (2026a). Su ürünleri istatistikleri 2024. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture. https://www.tarimorman.gov.tr/BSGM/Belgeler/Icerikler/Su%20Ürünleri%20Veri%20ve%20Dökümanları/Bsgm-istatistik.pdf

TRAF-GDFA. (2026b). Su ürünleri yetiştiricilik tesisleri 2025. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Fisheries and Aquaculture. https://www.tarimorman.gov.tr/BSGM/Belgeler/Icerikler/Su%20Ürünleri%20Yetiştiriciliği/Su-Urunleri-Tesisleri-2023.pdf

TRAF-GDSHW. (2024). DSİ faaliyet raporu 2023. Republic of Türkiye Ministry of

Agriculture and Forestry General Directorate of State Hydraulic Works https://cdniys.tarimorman.gov.tr/api/File/GetFile/425/Sayfa/759/1107/DosyaGaleri/dsi_2023_yili_faaliyet_raporu.pdf

TRAF-GDWM. (2020). İklim değişikliği ve uyum. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Belgeler/iklim%20değişikliğinin%20su%20kaynaklarına%20etkisi/iklimkitap2020.pdf

TRAF-GDWM. (2025a). Kuraklık yönetim planları. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Sayfalar/Detay.aspx?SayfaId=61

TRAF-GDWM. (2025b). Taşkın yönetim planları. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Sayfalar/Detay.aspx?SayfaId=53

TRAF-GDWM. (2025c). Nehir havza yönetim planları. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Sayfalar/Detay.aspx?SayfaId=49

TRAF-GDWM. (2025d). Havza koruma eylem planları. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Sayfalar/Detay.aspx?SayfaId=6

TRAF-GDWM. (2025e). Sektörel su tahsis planları. Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Water Manegement. https://www.tarimorman.gov.tr/SYGM/Sayfalar/Detay.aspx?SayfaId=10

TRAF-GDWM. (2025f). A Google Search for the Promotion of 25 Basins found PDF promotional brochures under the Documents tab at https://www.tarimorman.gov.tr › SYGM › Sample downloaded PDF file: https://www.tarimorman.gov.tr/SYGM/Belgeler/Havzalarımızı%20Tanıyalım/Meriç-Ergene%20Havzası%20Tanıtım.pdf

TREUC-CD. (2024). İklim değişikliğine uyum stratejisi ve eylem plani (2024-2030). Republic of Turkey Ministry of Environment, Urbanization and Climate Change, Climate Change Directorate. https://iklim.gov.tr/db/turkce/icerikler/files/İklim%20Değişikliğine%20Uyum%20Stratejisi%20ve%20Eylem%20Plan_%202024-2030.pdf

TSI. (2025). Fishery statistics. Turkish Statistical Institute Fishery Statistics. https://biruni.tuik.gov.tr/medas/?kn=97&locale=en

TSMS. (2025a). Resmi iklim istatistikleri. Turkish State Meteorological Service. https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=parametrelerinTurkiyeAnalizi

TSMS. (2025b). 2024 yili yağiş değerlendirmesi. Turkish State Meteorological Service. https://www.mgm.gov.tr/FILES/arastirma/yagis-degerlendirme/2024yagisdegerlendirmesi.pdf

TSMS. (2025c). Kuraklık analizi. Turkish State Meteorological Service. https://www.mgm.gov.tr/veridegerlendirme/kuraklik-analizi.aspx?d=aylik&k=pni#sfB

Turan, D., Kottelat, M. & Engin, S. (2009). Two new species of trouts, resident and migratory, sympatric in streams of northern anatolia (Salmoniformes: Salmonidae). *Ichthyological Exploration of Freshwaters*, *20*(4), 333-364.

Turan, D., Kalaycı, G., Bektaş, Y., Kaya, C., & Bayçelebi, E. (2020). A new species of trout from the northern drainages of Euphrates River, Turkey (Salmoniformes: Salmonidae). *Journal of Fish Biology*, *96*(6), 1454-1462. https://doi.org/10.1111/jfb.14321

Türkeş, M., Öztaş, T., Tercan, E., Erpul, G., Karagöz, A., Dengiz, O., Doğan, O., Şahin, K., & Avcıoğlu, B. (2020). Desertification vulnerability and risk assessment for Türkiye via an analytical hierarchy process model. *Land Degradation & Development*, *31*(2), 205-214. https://doi.org/10.1002/ldr.3441

Türkeş, M., & Yurtseven, N. (2025). Observed and projected geographical and temporal changes in the Köppen-Geiger climate types in Türkiye. *Theoretical and Applied Climatology*, *156*(154), 1-2.1 https://doi.org/10.1007/s00704-024-05346-2

Uzuner, Ç., & Dengiz, O. (2020). Desertification risk assessment in Turkey based on environmentally sensitive areas. *Ecological Indicators*, *114*, 106295. https://doi.org/10.1016/j.ecolind.2020.106295

World Bank Group. 2022. Türkiye Country Climate and Development Report. World Bank. http://hdl.handle.net/10986/37521 or https://www.worldbank.org/en/country/turkey/brief/key-highlights-country-climate-and-development-report-for-turkiye

Yılmaz, E., & Çiçek, İ. (2019). Türkiye'de Köppen-Geiger iklim tiplerindeki zamanmekansal değişimler. *Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi*, *59*(1), 181-202. https://doi.org/10.33171/dtcfdergisi.1044612

Supplementary Table 1. Provinces that do not have inland rainbow trout farming or whose total production and 2024 production share is less than 1% (TSI, 2025).

Basin Name	**Other**
1.Maritsa -Ergene	Çanakkale, Edirne, İstanbul, Kocaeli, Tekirdağ
2.Marmara	Balıkesir, Bilecik, Bursa, Çanakkale, İstanbul, İzmir, Kocaeli, Kırklareli, Kütahya, Manisa, Tekirdağ
3.Susurluk	Balıkesir, Çanakkale, İzmir, Manisa
4.Northern Aegean	Balıkesir, Bursa, Bilecik, Çanakkale, İzmir, Kütahya, Manisa
5.Gediz	Balıkesir, İzmir, Kütahya, Manisa, Uşak
6.Küçük Menderes	İzmir, Manisa
7.Büyük Menderes	Afyonkarahisar, İzmir, Kütahya, Manisa, Uşak
8.Western Mediterranean	Afyonkarahisar, Konya
9.Antalya	Afyonkarahisar
10.Burdur	Afyonkarahisar, Kütahya, Konya, Uşak
11.Akarçay	Afyonkarahisar, Ankara, Bilecik, Bolu, Bursa, Çankırı, Eşkişehir, Kocaeli, Konya, Kütahya, Sakarya, Uşak, Düzce
12.Sakarya	Ankara, Bolu, Çankırı, Kastamonu, Sakarya, Sinop, Zonguldak, Bartın, Karabük, Düzce
13.Western Black Sea	Ankara, Bolu, Çankırı, Kastamonu, Sakarya, Sinop, Zonguldak, Bartın, Karabük, Düzce
14.Yeşilırmak	Amasya, Çorum, Erzincan, Giresun, Ordu, Yozgat, Bayburt
15.Kızılırmak	Aksaray, Amasya, Ankara, Çankırı, Çorum, Erzincan, Kastamonu, Kırıkkale, Konya, Nevşehir, Niğde, Sinop, Yozgat
16.Konya Closed	Ankara, İçel, Konya, Nevşehir, Niğde, Aksaray, Karaman,
17.Eastern Mediterranean	İçel, Konya, Niğde, Karaman
18.Seyhan	İçel, Niğde, Osmaniye
19.Oronte	Gaziantep, Hatay, Kilis, Osmaniye
20.Ceyhan	Adıyaman, Hatay, Osmaniye
21. Euphrates-Tigris	Adıyaman, Ağrı, Bingöl, Bitlis, Diyarbakır, Erzincan, Kars, Hakkâri, Mardin, Muş, Siirt, Bayburt, Batman, Şırnak, Iğdır, Kilis
22. Eastern Black Sea	Giresun, Ordu Rize, Trabzon, Bayburt
23. Çoruh	Erzincan, Kars, Rize, Trabzon, Bayburt, Ardahan
24. Arax	Ağrı, Kars, Ardahan, Iğdır
25. Lake Van	Ağrı, Bitlis, Muş
∑	68

Supplementary Table 2. Future projections of Türkiye's basins in terms of temperature, precipitation and water reserves (TRAF-GDWM 2020).

Basin	T ^{0}C			Precipitation (mm)		Water reserve (millio m^3/year)		Water deficit (millio m^3/year)	Groundwater reserve (km^3)			
	1971 - 2000	2071-2100		1971-2000	2071-2100	1971-2000	2041(71)-2100	Until 2100	Hydrological		Possible	
		🌡		Present	💭	Present	💭		💭	21	💭	21
1. Maritsa -Ergene	13.4	1.5	4.7	598.3	-13%	1,838	-60%	1,485	188	-2%	125	-3%
2.Marmara	13.9	1.5	4.6	679.2	+13%	8,566	-50%	/	53	-6%	29	-10%
3.Susurluk	12.5	1.6	4.7	640	-10%	6,157	-50%	/	34	-6%	18	-11%
4.Northern Aegean	15.9	1.5	4.6	615	-15%	2,379	-60%	75	19	-11%	10	-21%
5.Gediz	14.6	1.7	4.9	589.7	-20%*	2,505	-75%	1,445	40	-11%	21	-20%
6.Küçük Menderes	16.7	1.6*	4.7*	695.6	-20%	1,369	-70%	315	56	-3%	32	-5%
7.Büyük Menderes	14.4	1.8*	5*	592.4	-25%*	4,028	-65%	2,480	228	-4%*	138	-7%*
8.Western Med.	16.2	1.8*	4.9*	731	-28%*	94.3	-50%	/	70	-13%*	43	-22%*
9.Antalya	14.2	1.8*	5*	690.5	-25%*	12,153	-60%	/	288	-7%*	168	-12%*
10.Burdur	12.3	1.9	5.1	508.7	-25%*	606	-85%	495	49	-14%	26	-26%
11.Akarçay	11.3	1.8	5	460.4	-17%*	678	-70%	545	105	-11%*	57	-20%*
12.Sakarya	11.3	1.7	4.9	477.8	-8%	8,592	-75%	1,175	377	-5%*	200	-10%*
13.W. Black Sea	11.6	1.6	4.7	741.6	+8%	10,346	/	/	93	-11%*	55	-18%*
14.Yeşilırmak	11.0	1.8	5	510.2	+6%	6,432	-30%	/	86	-9%	48	-17%
15.Kızılırmak	10.3	1.8	5.1	448.7	-6%*	8,011	-60%	2,160	494	-7%*	266	-13%*
16.Konya Closed	11.1	1.9	5.2	397.6	-16%*	6,532	-70%	4,490	518	-3%*	306	-6%*
17.Eastern Med.	16.0	2*	5.1*	629.1	-26%*	11,167	-60%	4,695	10	-10%	6	-13%
18.Seyhan	12.3	2	5.3	545.3	-15%*	8,711	-30%	2,325	112	-5%	70	-8%
19.Asi	18.0	1.8	5	804.6	-21%	1,572	-55%	270	16	-29%	9	-54%
20.Ceyhan	13.7	2	5.3	619.3	-20%*	8,165	-70%	2,650	76	-8%	41	-15%
21.Euph.-Tigris	12.0	2.3*	5.8*	584.5	-12%*	57,167	-60%	23,175	899	-2%*	473	-5%*
22.E. Black Sea	12.2	1.7	4.9	961.4	-15%	15,336	-60%	/	0.015	/	0.008	/
23.Çoruh	8.5	2	5.4	616.8	+10%	6,600	-20%	/	1	-5%	0.7	-7%
24.Arax	6.1	2.3	5.7	460.5	-5%*	4,886	-5%	/	21	-8%	14	-13%
25.Lake Van	8.0	2.2	6	527.6	+7%	2,569	-40%	/	14	-9%	7	-17%
Average	12.7	1.8	5.1	605.0	-11.9	7,858.4	-55%	3,185.3	153.9	-8%	86.5	-15%

🌡:min.&max.; Present:the current situation; 💭:expectation; 21:end of century; and /: sufficient. It refers to the basins that remain above the average values of the maximum and minimum increase or just increase values of the years 2071-2100 and 2041-2100 added to the average values of the reference year (1971-200). Western Med.: Western Mediterranean, W. Black Sea: Western Black Sea, Eastern Med.: Eastern Mediterranean, Euph.-Tigris: Euphrates-Tigris, E. Black Sea: Eastern Black Sea.