



# Potential anthropogenic and climatic factors affecting Iran's international wetlands

Ehsan Rahimi<sup>1</sup> · Mojtaba Jahandideh<sup>2</sup> · Pinliang Dong<sup>3</sup> · Faraham Ahmadzadeh<sup>4</sup>

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## Abstract

Human development has reached more than 80% of the earth's surface and in Iran has had devastating effects on aquatic ecosystems such as wetlands. In addition to human development, climate change is also an important factor that threatens the health of Iran's wetlands. Very few studies have examined the major threats to Iran's international wetlands, and it is not clear to what extent these wetlands are affected by anthropogenic and climatic pressures. Therefore, determining how vulnerable these ecosystems are to human development and climate change can help us better manage and restore them. In this regard, this study is aimed at measuring the changes in water bodies of 24 international wetlands when comparing late summer 2000 and 2020 using Landsat images. Next, we calculate the upstream dams' water bodies and discover the long-term trend of precipitation and temperature changes around the wetlands. Our results show that nine wetlands, most of which were marine and estuarine, increased in area between 2000 and 2020. However, eleven wetlands experienced a 1.0–53.5% decrease in their water area by 2020. Our findings suggest that climate change can be a significant factor affecting some of the wetlands studied. Conversely, certain wetlands have experienced a rising trend in precipitation between 2000 and 2020, making it challenging to link the decline in their water levels to climate change. Nevertheless, for seven of the wetlands, we observe an increase in the water areas of upstream dams between 2000 and 2020 and find no strong evidence for climate change effects. Therefore, the construction of dams upstream may be the primary reason for the drying of these wetlands, and in this case, more of a threat than climate change.

**Keywords** Iran · Wetland conservation · Climate change · Dam construction

Ehsan Rahimi and Faraham Ahmadzadeh contributed equally.

✉ Ehsan Rahimi  
ehsanrahimi666@gmail.com  
Mojtaba Jahandideh  
mojtaba.jahandide@gmail.com  
Pinliang Dong  
Pinliang.Dong@unt.edu  
Faraham Ahmadzadeh  
f\_ahmadzade@sbu.ac.ir

<sup>1</sup> Shahid Beheshti University, Tehran, Iran

<sup>2</sup> Department of Environment, The Conservation of Iranian Wetlands Project, Tehran, Iran

<sup>3</sup> Department of Geography and the Environment, University of North Texas, Denton, TX, USA

<sup>4</sup> Department of Biodiversity and Ecosystem Management, Environmental Sciences Research Institute, Shahid Beheshti University, Tehran, Iran

## Introduction

Despite covering 6% of the Earth (Mitsch et al. 2010), wetlands provide 40% of the world's ecosystem services (Zedler and Kercher 2005). It was estimated that 50% of the world's wetlands have become extinct since 1990 (Wang et al. 2011), which is largely caused by human activities. Human development is transforming more than 80% of terrestrial lands (Sanderson et al. 2002) and has significantly affected natural ecosystems (Venter et al. 2016). In general, environmental pressures on wetlands are primarily due to human activities such as dam construction, agriculture, the entry of industrial and domestic wastewater, wood harvesting, and vegetation from wetlands for fuel (Ghazali 2012; Malekmohammadi and Jahanishakib 2017; Wang et al. 2020; Zedler and Kercher 2005).

The existence and size of the wetland water bodies depend on the balance between water input due to precipitation and groundwater and water losses because of

evaporation from the surface of the wetland (Salimi et al. 2021). In this regard, climate change can be an important threat that causes changes in the water bodies of wetlands (Erwin 2009; Sanjerehei and Rundel 2017). For example, Reiter et al. (2018) suggest that during drought periods, the area of managed wetlands in California's Central Valley is reduced by 39 to 60%. Chu (2011) assessing the potential effects of climate change on wetlands within the Simcoe basin found that 89% of wetlands within the basin were vulnerable to climate changes. Ebrahimi-Khusfi et al. (2020) showed that climate change reduces soil moisture in wetlands and causes dust generation. Global temperatures are predicted to rise by an average of 2 to 4 °C by 2050 due to greenhouse gas emissions (Pachauri et al. 2014). Increasing temperatures in the future could endanger the life of wetlands, so it is necessary to study the effects of climate change on the current and future status of wetlands. However, after reviewing 250 articles on the effects of climate change on wetlands and their restoration, Erwin (2009) found that little attention had been paid to this issue.

Iran, dominated by an arid and semi-arid climate, is located in southwest Asia and harbors more than 250 wetlands with an area of 2.5 million hectares (Sajedipour et al. 2017), of which 25 wetlands with an area of 1,655,449 hectares are on the international list of Ramsar Convention (Halls 1997). Unfortunately, six of the Iran's wetlands are on the Montreux list, including Neyriz Lake and Kamjan Marshes, Shadegan Marshes, Mudflats of Khor-al Amaya, and Khor Musa, Anzali Mordab, and Shurgol, Yadegarlu, and Dorgeh Lakes. The Montreux list includes wetlands that have undergone severe ecological change or are likely to undergo major changes soon. Most of Iran's international wetlands were included in the list of wetlands of the Ramsar Convention in 1975. The water body origin of wetlands is used as an indicator for the classification of wetlands (Gilvear and McInnes 1994). In addition, this index can provide valuable information about the vulnerability of wetlands to climate change and human activities. Iranian wetlands are divided into four groups based on the source of incoming water (Salmanmahine and Safidiyan 2013); ombrotrophic, rheotrophic, minerotrophic, and omnitrophic. Ombrotrophic is composed of precipitation; rheotrophic is composed of surface waters; minerotrophic is composed of groundwater, and omnitrophic is composed of all water sources (Gilvear and McInnes 1994). Most of Iran's wetlands are in the rheotrophic group.

The state of water resources in Iran is also not favorable, and studies (Ashraf et al. 2021; Moridi 2017; Vaghefi et al. 2019) show that this situation is getting worse year by year. For example, the average rainfall in Iran between 1994 and 2014 was about 228 mm/year, which is 6% less than the long-term average. The average volume of surface runoff in this period is reported to be 52 billion cubic

meters, which is 42% less than the long-term average. Agricultural water consumption increased from four billion cubic meters in 1961 to 80 billion in 2001 and 86.5 billion in 2011 (Moridi 2017). Therefore, 7% of Iran is under severe groundwater overdraft, which leads to the depletion of aquifers, and as a result, the wetlands fed by these aquifers dry up. Approximately 92% of the allocated water in Iran is used in the agricultural sector, and there are about 650,000 agricultural wells in Iran. Also, ~77% of Iran is under extreme groundwater overdraft, which has led to significant groundwater depletion (Ashraf et al. 2021). The flow of Iran's rivers also decreased by 42% between 2005 and 2013. Recent studies also claimed that compared to the period 1980–2004, in the period 2025–2049, Iran is likely to experience wider periods of extreme maximum temperatures in the southern parts of the country (Vaghefi et al. 2019 898).

Some studies suggest that climate change is the most significant threat to these wetlands, particularly Lake Urmia (Alborzi et al. 2018; Delju et al. 2013). However, other research argues that dam construction is the main factor behind the lake's drying. To develop effective management strategies for these wetlands, it is essential to assess their current status and identify the factors that contribute to changes in their water bodies. Unfortunately, no study has comprehensively examined changes in all of Iran's Ramsar site wetlands. Therefore, this study is aimed at filling this knowledge gap by measuring changes in the water bodies of Iran's international wetlands between 2000 and 2020. The study will also investigate changes in precipitation and temperature around these wetlands during this period and evaluate water body changes behind the upstream dams of these wetlands. Overall, this study seeks to determine the possible reasons for changes in the water bodies of Iran's wetlands, whether due to climate change or human activities such as dam construction.

## Methods

### Study area

Figure 1 shows the location of Iran's international wetlands and their basin. In this figure, the position of each wetland is marked with a yellow circle, and a number is assigned to each wetland. The characteristics of each wetland are presented in Table 1. This table presents the name, geographical coordinates, area, elevation, type of wetland, and year of inclusion of the wetlands to the list of Ramsar wetlands. The lowest area belongs to Lake Gori with 219 hectares, and the largest wetland in Iran is Lake Urmia with an area of 540,728 hectares.

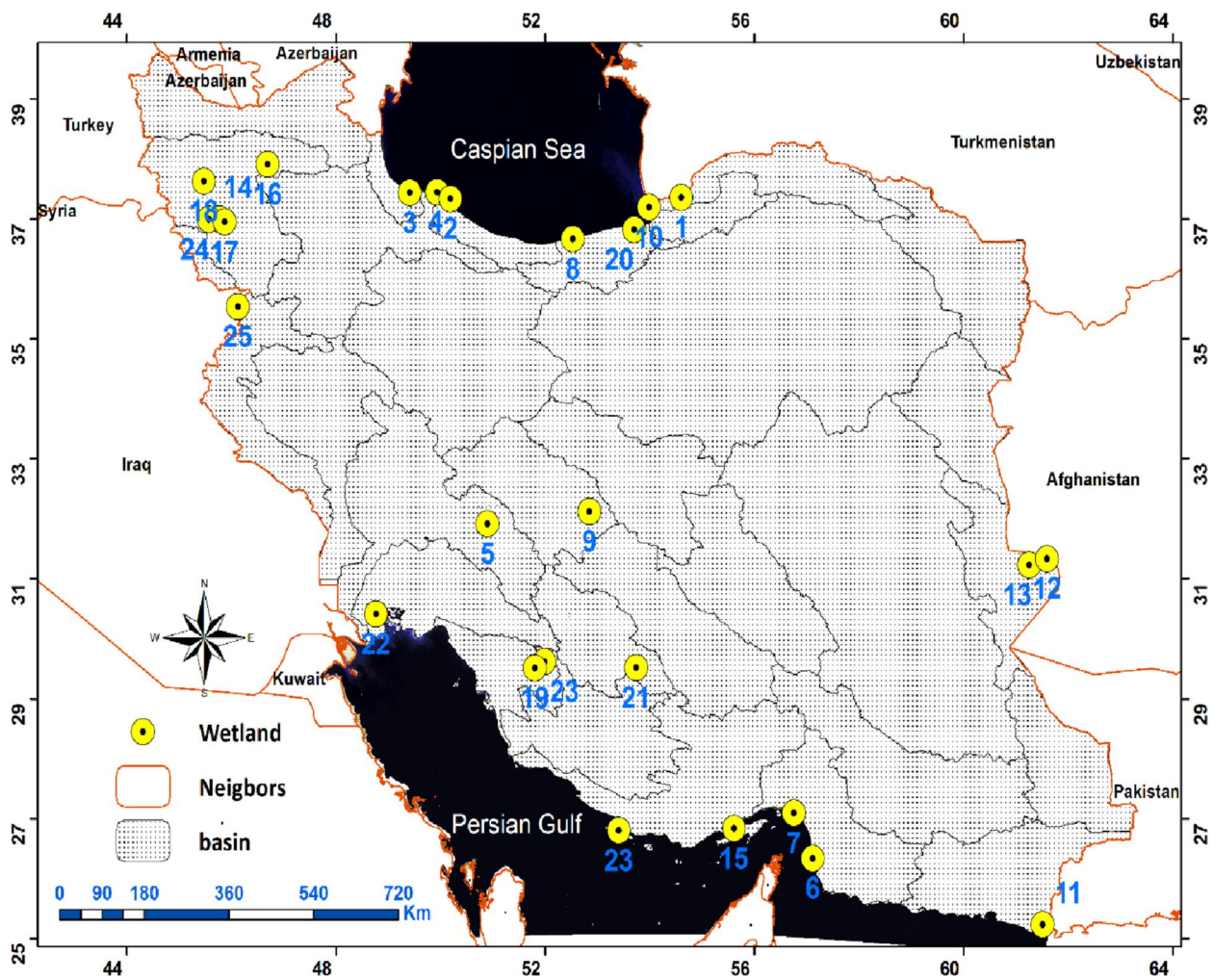


Fig. 1 Location of Iran's international wetlands along with their basins

## Overview of methodology

The primary objective of this study is to investigate two main hypotheses about the decline of Iran's international wetlands' water level. These hypotheses are related to two factors: (1) changes in climatic conditions and (2) the construction of dams upstream of the wetlands. While other variables such as roads and agricultural activities may impact water quantity and quality in the wetlands (Rahimi and Dong 2022), this research only focuses on the potential effects of the mentioned factors on the wetlands under study.

The evaluation of the potential threats to Iran's wetlands from dam construction upstream and climate change is presented in Fig. 2. This flowchart outlines the methodology used in this study. Initially, satellite images are utilized to calculate the waterbody areas of the wetlands from 2000 to 2020. The wetlands that did not experience a reduction in their areas in 2020 were considered to have a low risk and were thus excluded from the study. This decision was based

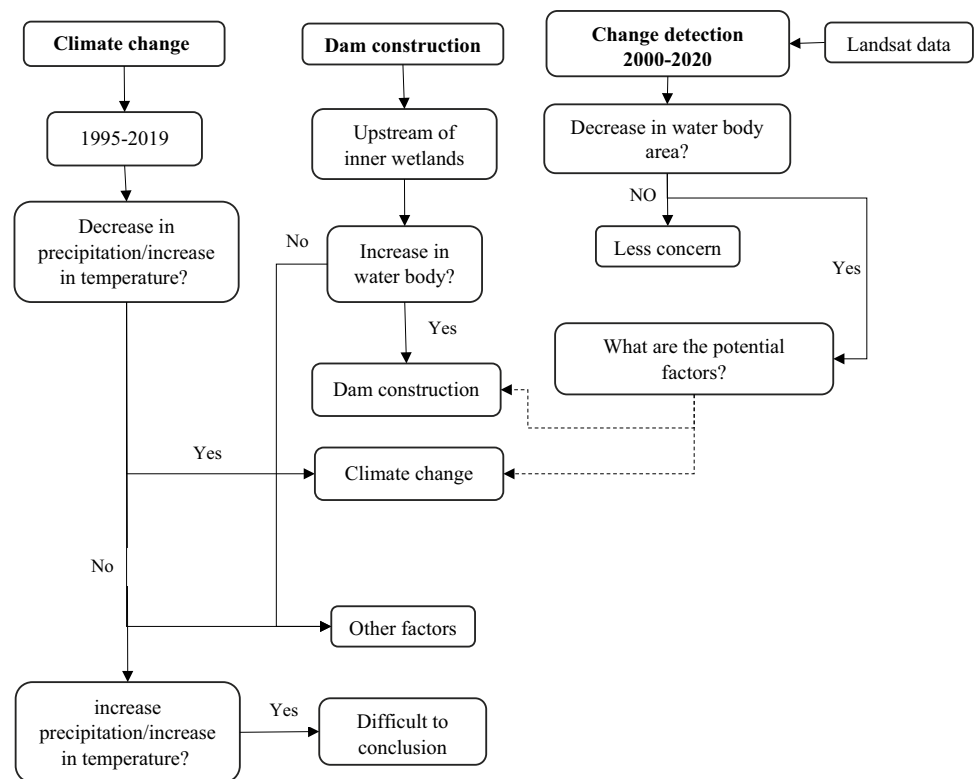
on the premise that assessing the impact of dam construction and climate change on these wetlands would not be significant. However, if a wetland's area has decreased, the two hypotheses of dam construction and climate change must be examined. If a dam exists upstream of the wetland, there is a possibility that the rainfall water is trapped behind the dam and cannot reach the wetland. Alternatively, there may not have been sufficient rainfall in the watershed, resulting in limited water entering the dam and wetland. If the water level behind the dam has increased between 2000 and 2020, but the water area of the wetland has decreased, this indicates that rainfall has occurred in the upstream watershed, but the water has not flowed into the wetland. Therefore, dams may be considered an important factor contributing to the reduction of the water level of the wetland.

Some wetlands do not have any dams upstream, so the hypothesis that dam construction is causing dryness in those wetlands is fundamentally rejected. In such cases, other factors, such as climate change, need to be evaluated. This

**Table 1** The name, geographical coordination, area, elevation (m), type of wetland, and year of inclusion of the wetlands to the list of Ramsar wetlands

No	Name	Coordinate	Area (ha)	Elevation	Year	Type
1	Alagol, Ulmagol, and Ajigol Lakes	54 35 E 37 21 N	3138	5	1975	Rheotrophic
2	Amirkelayeh Lake	50 12 E 37 17 N	1084	-20	1975	Minerotrophic
3	Anzali Mordab	49 29 E 37 25 N	19484	-23	1975	Omnitrophic
4	Bujagh National Park*	49 55 E 37 20 N	3432	-25	1975	Marine- Rheotrophic
5	Choghakhor Wetland	52 52 E 32 08 N	2438	2100	2010	Rheotrophic
6	Deltas of Rud-e-Gaz and Rud-e-Harra*	52 20 E 26 40 N	23766	0	1975	Rheotrophic
7	Deltas of Rud-e-Shur, Rud-e-Shirin and Rud-e-Minab*	56 45 E 27 05 N	46667	0	1975	Marine-Rheotrophic
8	Fereydonkenar, Ezbaran and Sorkh Ruds Ab-bandans	52 33 E 36 40 N	5436	-23	1975	Rheotrophic
9	Gavkhouni Lake and marshes of the lower ZaindehRud	52 47 E 32 20 N	65562	1470	1975	Rheotrophic
10	Gomishan Lagoon*	53 57 E 37 11 N	18094	-27	2001	Marine- Rheotrophic
11	Govater Bay and Hur-e-Bahu*	61 30 E 25 10 N	29485	0	1999	Marine- Rheotrophic
12	Hamon-e-Puzak, South end	61 45 E 31 20 N	28873	490	1975	Rheotrophic
13	Hamon-e-Saberi and Hamlm-e-Hirmand	61 20 E 31 20 N	57198	470	1975	Rheotrophic
14	Kanibarazan Wetland	45 46 E 36 59 N	876	1280	2010	Rheotrophic
15	Khuran Straits*	55 40 E 26 45 N	87874	0	1975	Marine
16	Lake Gori	37 55 E 46 42 N	219	1890	1975	Minerotrophic
17	Lake Kobi	45 30 E 36 57 N	935	1240	1975	Rheotrophic
18	Lake Urmia	45 30 E 37 30 N	540728	1280	1975	Rheotrophic
19	Lake Parishan and Dasht-e-Arjan	51 48 E 29 31 N	9000	853	1976	Rheotrophic
20	Miankaleh Peninsula, Gorgan Bay, and Lapoo-Zaghmarz Ab-Bandan*	53 17 E 36 50 N	95969	-27	1975	Marine- Rheotrophic
21	Neyriz Lake and Kamjan Marshes	53 30 E 29 40 N	126695	1540	1975	Rheotrophic
22	Shadegan Marshes, Mudflats of Khor-al Amaya and Khor Musa*	48 45 E 30 30 N	488325	0	1975	Marine- Rheotrophic
23	Sheedvar Island	53 24 E 26 48 N	870	8	1999	Marine
24	Shurgol, Yadegarlu and Dorgeh Lakes	45 30 E 37 00 N	2320	1290	1975	Rheotrophic
25	Zarivar Lake	46 07 E 35 32 N	1950	1285	2018	Rheotrophic

\*Marine/estuarine wetlands

**Fig. 2** Flowchart of methodology

study employed climatic data on temperature and precipitation from the closest meteorological station to the wetlands between 1995 and 2019. If there is a decrease in precipitation and an increase in temperature during this period; then, climate change can be considered a threat to the wetland under investigation. If the decrease in precipitation and increase in temperature is not significant, other threatening factors should be investigated. However, if the temperature rises between 1995 and 2019, leading to the evaporation of wetland water, and precipitation also increases during this period, making it challenging to differentiate the effects of the two factors; then, the conclusion about the impacts cannot be drawn. On the other hand, if there is a dam upstream of a wetland, and there is an increase in the water area of the dam, coupled with a rise in temperature and a decrease in precipitation, both these factors are considered to be harmful to the wetland.

### Waterbody classification and change detection

To measure the changes in the water bodies of Iran's international wetlands, we used Thematic Mapper (TM) images of the Landsat 5 satellite and Operational Land Imager (OLI) images of the Landsat 8 satellite in the years 2000 and 2020, respectively. Landsat 8 OLI sensor and Landsat 5 TM sensor have a spatial resolution of 30 m and a 12-bit and 8-bit radiometric resolution, respectively. The images are freely available at the Landsat archive at the United States Geological

Survey (USGS) (<http://glovis.usgs.gov>). We applied the maximum likelihood algorithm to classify Landsat images for calculating the area of wetland water bodies. The study area was classified into two classes, including the water body and other covers. In this study, we measured the area of water bodies in the worst conditions of the wetlands, i.e., in late summer. In late summer, the water level of the wetlands reaches its lowest level, and if the wetlands are in a suitable condition during this period, their conditions are favorable in other seasons as well, and they are not in a critical state. We restricted our classification to only waterbodies that were distinguishable from other surfaces based on their reflection in satellite images. The accuracy of our classification was assessed through the use of ArcGIS software and a visual evaluation method. The classified areas were then compared with satellite images to ensure that they were accurately identified.

### Dam construction

Our study hypothesized that human activities, such as the construction of dams upstream of wetlands, could have a considerable impact on the wetlands. To investigate this, we identified all dams within the basin surrounding the wetlands that obstructed the flow of rivers leading to the wetlands. We then used satellite images to classify the water bodies of these dams in the years 2000 and 2020 and calculated the changes in their area unit. We only considered dams from

which released water flowed into the desired wetland. We used a paired *t*-test to determine if there is a significant difference between the means of dam water bodies area in the years 2000 and 2020.

### Climatic factors

Apart from human activities, climatic changes can also have an impact on the water balance of wetlands. Therefore, to explore the possible effects of climatic variables such as temperature and precipitation, we analyzed meteorological data from the Iran Meteorological Organization ([www.irimo.ir](http://www.irimo.ir)) for the nearest meteorological station around the wetland from 1995 to 2019 (Appendix).

## Results

### Waterbody changes detection

The Landsat image classified maps between 2000 and 2020 for international wetlands are presented in Figs. 3 and 4. Wetlands that have decreased in 2020 are illustrated in Fig. 3, while those that have increased are depicted in Fig. 4. The blue-colored areas in the images represent water bodies belonging to 2000, whereas the red-colored areas represent water bodies belonging to 2020. These figures do not display wetlands that were dry during the two periods studied. Table 2 provides the percentage of water body changes in Iran's international wetlands between 2000 and 2020. The results show that the water body area of nine wetlands examined in this study has increased in 2020. The range of this increase varies between 1% in the Deltas of Rud-e-Gaz and Rud-e-Harra and 20% in the Deltas of Rud-e-Shur, Rud-e-Shirin, and Rud-e-Minab. The wetlands with the largest increase in the water body in 2020 are Deltas of Rud-e-Shur, Rud-e-Shirin, and Rud-e-Minab (20%), followed by Kani-barazan Wetland, and Shurgol, Yadegarlu, and Dorgeh Lakes (17% and 10%, respectively). On average, the area of these nine wetlands increased by 7.6% in 2020 compared to 2000.

On the other hand, the area of eleven wetlands has declined from 2000 to 2020, with a reduced range of –1% to –53.5%. Four of these wetlands have turned into seasonal wetlands that only contain water during the rainy months after being dried in the late summer of both 2000 and 2020. Gomishan Lagoon has experienced the most significant reduction in water body area (–53.5%), followed by Alagol, Ulmagol, and Ajigol Lakes (–39%), Lake Parishan and Dasht-e-Arjan (–34%), and Lake Urmia (–29%). The average area reduction of these eleven wetlands is –19.7% between 2000 and 2020, as indicated in Table 2.

### Climatic and dam construction pressures

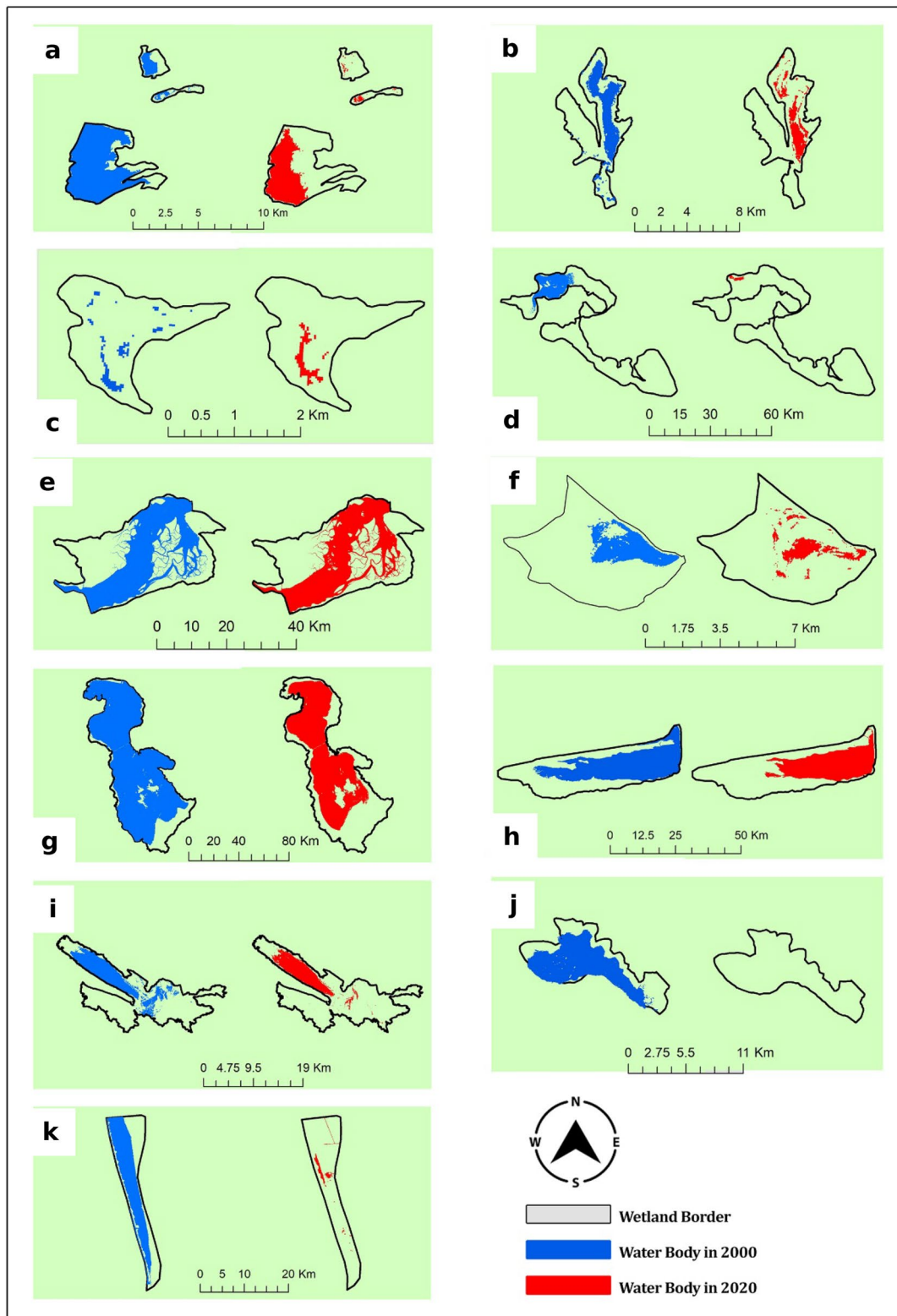
Table 3 presents the trends in air temperature (°C), precipitation (mm), and the area of water bodies in dams (Ha) for wetlands whose areas have decreased in 2020. The data in the table indicates that Alagol, Ulmagol, Ajigol Lakes, and Choghakhor Wetland experienced a decrease in temperature but an increase in precipitation in 2020. In contrast, Hamon-e-Puzak, South end, Hamon-e-Saberi, and Hamlm-e-Hirmand experienced an increase in temperature but a decrease in precipitation. Some wetlands experienced an increase in both temperature and precipitation.

Table 3 indicates that Neyriz Lake and Kamjan Marshes had the highest area of dam water bodies among the studied wetlands in 2000. Hamon-e-Puzak, South end, Hamon-e-Saberi, and Hamlm-e-Hirmand were ranked second, with a total of 2112 hectares of dam water bodies in 2000. The area of dam water bodies has increased for all wetlands studied in 2020 compared to 2000. The largest increase in the area was observed in Lake Urmia, where the area of dam water bodies in its basin increased from 522 hectares in 2000 to 2097 hectares in 2020. Neyriz Lake and Kamjan Marshes also experienced significant increases in upstream dams in 2020. Table 4 shows that the *t*-test results indicate a significant difference between the mean area of dam water bodies in 2020 and 2000.

## Discussion

In this study, remote sensing data were utilized to examine alterations in the water body of Iran's international wetlands. The research delved into changes in the water behind dams, precipitation, and temperature surrounding these wetlands between 2000 and 2020. The findings revealed that the area of water bodies in nine wetlands increased in 2020 in comparison to 2000. Nonetheless, the area of eleven wetlands decreased in 2020, and four wetlands remained dry during both periods. The analysis was limited to examining potential factors for wetlands that experienced a decrease in their areas in 2020. The Sheedvar Island was not evaluated in this study.

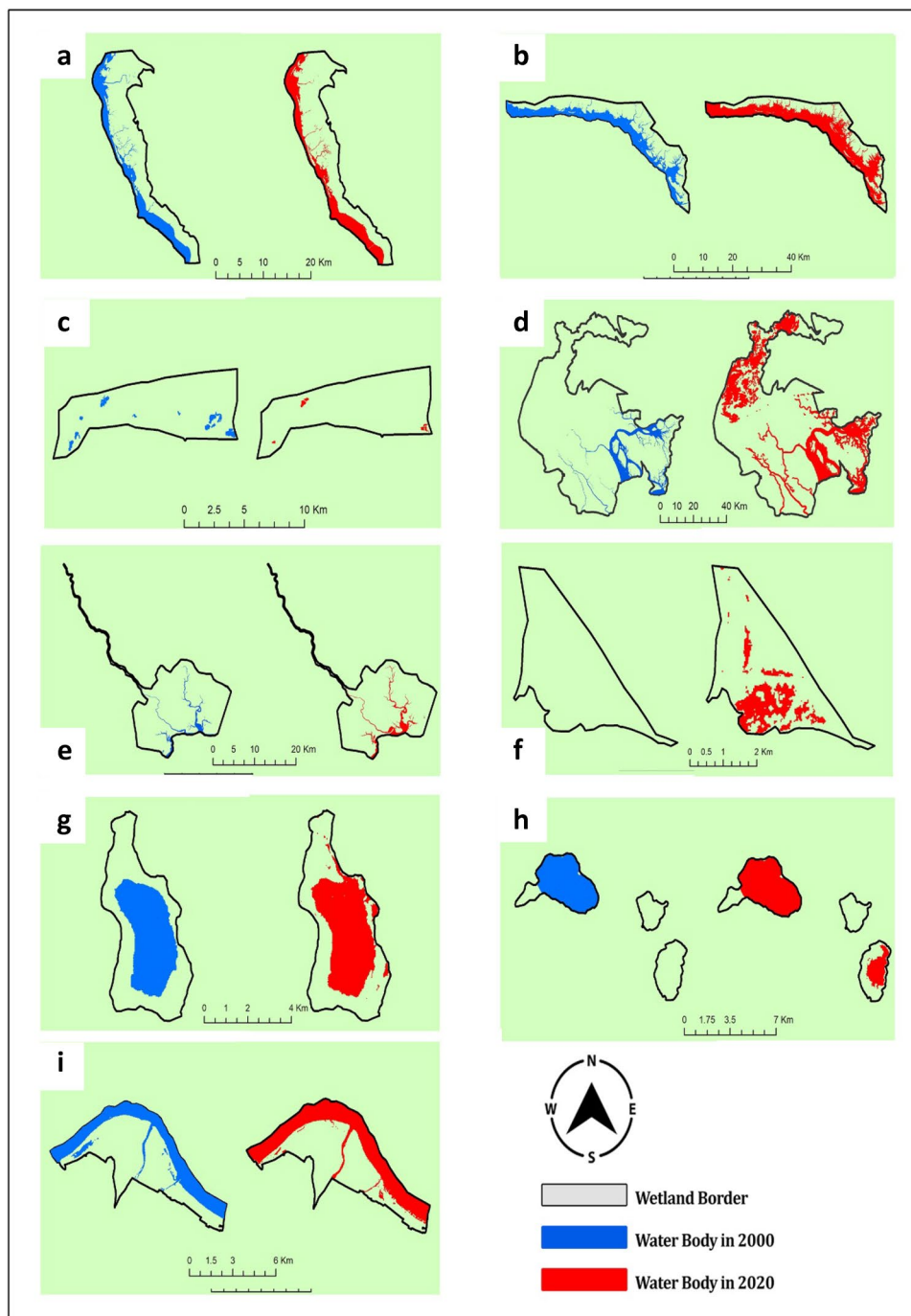
Our results indicated that Lake Urmia's water area decreased by 29% in 2020 compared to 2000. Although precipitation and temperature trends around the wetland increased in 2020, it is difficult to attribute the decrease in water level solely to evaporation due to the temperature increase. This suggests that climate change may not be the main reason for the reduction in water level, as precipitation has increased between 2000 and 2019. One potential factor contributing to this decrease is the construction of dams, as our study identified several large and small dams upstream of Lake Urmia that limit the flow of surface water into the wetland. Other studies have also indicated that the construction of dams is one of the most significant threats to Lake



**Fig. 3** Water bodies change in wetlands that have decreased in 2020. (a) Alagol, Ulmagol, and Ajigol Lakes; (b) Amirkelayeh Lake; (c) Lake Gori; (d) Neyriz Lake and Kamjan Marshes; (e) Khuran Straits;

(f) Choghakhor Wetland; (g) Lake Urmia; (h) Miankaleh Peninsula, Gorgan Bay, and Lapoo-Zaghmarz Ab-Bandan; (i) Anzali Mordab; (j) Lake Parishan and Dasht-e-Arjan; and (k) Gomishan Lagoon

**Fig. 4** Water bodies change in wetlands that have increased in 2020. (a) Deltas of Rud-e-Gaz and Rud-e-Harra; (b) Deltas of Rud-e-Shur, Rud-e-Shirin, and Rud-e-Minab; (c) Fereydonkenar, Ezbaran, and Sorkh Ruds Ab-bandans; (d) Shadegan Marshes, Mudflats of Khor-al Amaya and Khor Musa; (e) Govater Bay and Hur-e-Bahu; (f) Kanibarazan Wetland; (g) Zarivar Lake; (h) Shurgol, Yadegarlu, and Dorgeh Lakes; and (i) Bujagh National Park



Urmia (Alborzi et al. 2018). The study by Delju et al. (2013) also revealed that the average rainfall trend in Lake Urmia decreased between 1964 and 2005. However, our findings are consistent with the results of Rahimi and Breuste (2021), which indicated that changes in the lake's water level were minor between 1987 and 2000, but intensified significantly from 2000 to 2010, resulting in a loss of almost 28% of the lake's water level. Their study suggested that climate change did not have a significant impact on the lake's changes and that dam construction was a crucial factor in the lake's drying.

According to our data, the amount of rainfall around Alagol, Ulmagol, and Ajigol Lakes has increased, and the temperature has decreased. Therefore, we cannot conclude that climate change has had a significant impact on the water bodies of these wetlands. Moreover, there are now several dams upstream of these wetlands that did not exist in 2000, and these dams have limited the flow of surface water. Therefore, the presence of dams may be one of the significant reasons for the large reduction in the water bodies of these wetlands in 2020.



**Table 2** The amount and percentage of changes in the water bodies of Iran’s international wetlands between 2000 and 2020

Name	Area (Ha)				
	2000	%	2020	%	Change %
Alagol, Ulmagol, and Ajigol Lakes	2265	72	1046	33	− 39
Amirkelayeh Lake	326	30	167	15	− 15
Anzali Mordab	5306	27	3432	17	− 10
Bujagh National Park	1209	35	1479	43	+ 8
Deltas of Rud-e-Gaz and Rud-e-Harra	6848	28	7030	29	+ 1
Deltas of Rud-e-Shur, Rud-e-Shirin, and Rud-e-Minab	17455	37	26916	57	+ 20
Fereydonkenar, Ezbaran, and Sorkh Ruds Ab-Bandans	172	3	44	0.8	+ 2.2
Gavkhouni Lake and marshes of the lower ZaindehRud	0	0	0	0	0
Gomishan Lagoon	10370	57	637	3.5	− 53.5
Govater Bay and Hur-e-Bahu	1501	5	1988	6	+ 1
Hamon-e-Saberi and Hamlm-e-Hirmand	0	0	0	0	0
Hamon-e-Puzak, South end	0	0	0	0	0
Khuran Straits	42779	48	40517	46	− 2
Lake Gori	12	5.5	10	4.5	− 1
Lake Kobi	0	0	0	0	0
Lake Urmia	455132	84	301380	55	− 29
Lake Parishan and Dasht-e-Arjan	3147	34	0	0	− 34
Miankaleh Peninsula, Gorgan Bay, and Lapoo-Zaghmarz Ab-Bandan	51,393	53	36678	38	− 15
Neyriz Lake and Kamjan Marshes	16,663	13	915	0.72	− 12.2
Shadegan Marshes, Mudflats of Khor-al Amaya and Khor Musa	31783	6.5	57866	11	+ 5.5
Shurgol, Yadegarlu and Dorgeh Lakes	1161	50	1404	60	+ 10
Kanibarazan Wetland	0	0	156	17	+ 17
Choghakhor Wetland	407	16	222	9	− 7
Zarivar Lake	811	41	915	46	+ 5

**Table 3** The area of dam water bodies (Ha), temperature (C), and precipitation (mm) trends of wetlands whose areas have decreased in 2020

Name	Dam		TEMP	PRCP
	2000	2020		
Alagol, Ulmagol, and Ajigol Lakes	0	367	↓	↑
Amirkelayeh Lake	-	-	↑	↑
Anzali Mordab	-	-	↑	↑
Choghakhor Wetland	-	-	↓	↑
Gavkhouni Lake and marshes of the lower ZaindehRud	1098	1352	↑	↔
Hamon-e-Puzak, South end	2112	3147	↑	↓
Hamon-e-Saberi and Hamlm-e-Hirmand	2112	3147	↑	↓
Lake Gori	-	-	↑	↑
Lake Urmia	522	2097	↑	↑
Lake Parishan and Dasht-e-Arjan	-	-	↔	↓
Neyriz Lake and Kamjan Marshes	2688	5300	↑	↑

↑ increase, ↓ decrease, ↔ no trend

The complete drying of Lake Parishan and Dasht-e-Arjan in 2020 has turned them into seasonal wetlands. Our analysis showed that there are no dams upstream of this wetland. Therefore, it can be inferred that climate change may be the reason for the drying of this wetland. Our data indicated a decreasing trend in rainfall around this wetland, which may have contributed to the drying up of Lake Parishan and Dasht-e-Arja. The Amirkelayeh Lake in northern Iran is primarily fed by groundwater, and the presence of agricultural wells in the surrounding area can harm its water supply. Unlike some of the other wetlands studied, there are no dams upstream of this lake, and long-term trends show an increase in rainfall. Therefore, it is likely that factors other than climate change or dam construction, such as agricultural activities, are contributing to the reduction in the size of this wetland.

According to our study, in the north of Iran, the Miankaleh Peninsula, Gorgan Bay, and Lapoo-Zaghmarz Ab-Bandan wetlands experienced a 15 percent decline in water level in 2020. The long-term decrease in rainfall can be considered factors contributing to the reduction of water level. However, it is important to note that these wetlands are categorized as marine wetlands, and their area is primarily influenced by fluctuations in the Caspian Sea. Therefore, changes in the sea level may also have played a role in the

**Table 4** Results of the paired *t*-test to determine the mean difference between 2000 and 2020

Variable	Null hypothesis	Year	<i>N</i>	Mean	StDev	SE Mean	DF	<i>T</i> value	<i>P</i> value
Dam	Mean 2020 > mean 2000	2000	6	1422	1048	427	5	-3.23	0.012
		2020	6	2568	1713	699			

*StDev*, standard deviation; *SE Mean*, standard error; *DF*, degree of freedom

observed decline in water level. In 2020, the area of Neyriz Lake and Kamjan Marshes decreased by 12%. Despite a long-term increase in precipitation trend from 1995 to 2019, the dryness of this wetland may be attributed to the existence of upstream dams that restrict surface water flow into the wetland.

Anzali Wetland, located in Iran, experienced a 10% decrease in its area in 2020. The long-term precipitation trend in this wetland has been increasing, which suggests that climate change is not a significant factor in water reduction. However, the existence of a wide activities in the area may limit the flow of surface water into this wetland. Anzali Wetland is an omnitrophic wetland, which means it is fed by various water sources. Agricultural wells around the wetland can harm the water availability in the wetland.

Choghakhor wetland experienced a 7% reduction in its area in 2020. Although there has been a rising trend in precipitation and a decreasing trend in temperature from 1995 to 2020, it is unlikely that climate change is the primary cause of the wetland's drying up. Instead, the decline may be attributed to human activities such as agriculture. Pirali Zefrehei et al. (2020) reported a 12% increase in the area of built-up and agricultural lands around the wetland from 1985 to 2018, indicating a possible impact on the water sources.

The two wetlands of Hamon-e-Saberi and Hamlm-e-Hirmand and Hamon-e-Puzak in southeastern Iran have become seasonal wetlands due to their complete drying in the late summer of 2000 and 2020. These wetlands also experienced a period of severe drought between 2000 and 2001 (Sharifikia 2013). The trend of rainfall in these wetlands has been downward, and the presence of the Kajaki dam in Afghanistan upstream of the Hirmand River has further limited the entry of surface water into the wetlands. The decreased rainfall and reduced amount of water entering the Hirmand River are among the main reasons for the drought in Hamoon. The upstream areas of the Helmand Basin are surrounded by agricultural activities, which also put significant pressure on the downstream Hamun Wetlands (Maleki et al. 2019; Najafi and Vatanfada 2011).

## Conclusion

In the present study, we examined the status of 24 international wetlands in Iran over 20 years. We found that nine of these wetlands were in suitable condition and had not experienced reductions. However, other wetlands have had

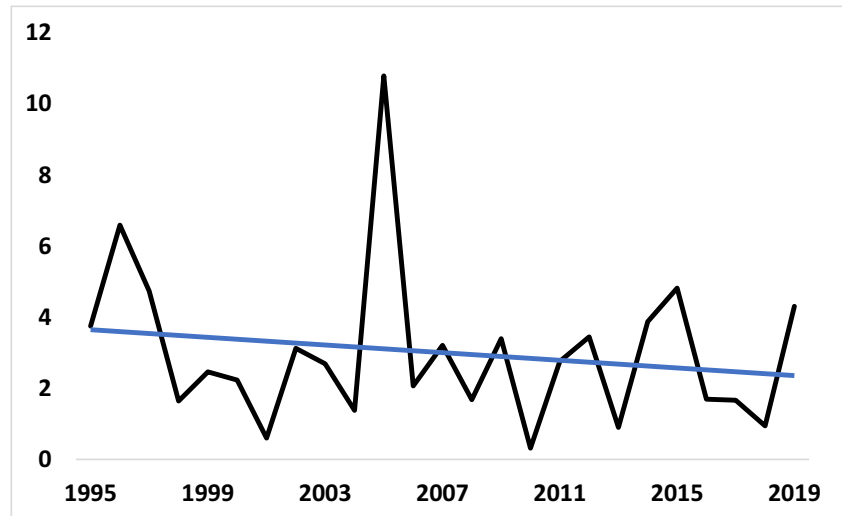
a significant reduction in their water area between 2000 and 2020. By comparing changes in water level over time with dam construction, temperature, precipitation, and patterns of agricultural use, we seek to shed light on the possible factors that reduced the water level of the wetlands. We found that for six cases (Hamon-e-Puzak, South end, Hamon-e-Saberi, and Hamlm-e-Hirmand, Gavkhouni Lake and marshes of the lower ZaindehRud, Lake Urmia, Alagol, Ulmagol, Ajigol Lakes and Neyriz Lake and Kamjam Marshes), water area reduction is most likely attributable to dam construction. In one case (Lake Parishan and Dasht-e-Arjan), water area reduction may be attributable to climate change, as these areas experienced both an increase in temperature and a decrease in precipitation. Miankaleh Peninsula, Gorgan Bay, Hamon-e-Saberi and Hamlm-e-Hirmand, Hamon-e-Puzak, and Lapoo-Zaghmarz Ab-Bandan experienced decreasing rainfall; therefore, their changes may be impacted by climate impacts. In some cases, dams were not present and precipitation increased (Amirkelayeh Lake and Choghakhor wetland) leading to the conclusion that agricultural activities play a role in reducing their water area. Other factors like the expansion of agricultural fields around Iran's wetlands can affect them and have been recognized as one of the important threats to Iran's protected areas (Rahimi and Dong 2022, 2023). Therefore, the effects of such activities can be studied in a separate study. Gomishan Lagoon and Khuran Straits are subject to the rise and fall of sea water levels, which can cause temporary decreases in their water levels. Factors such as tides, storm surges, and changes in coastal conditions can contribute to these fluctuations. It is important to consider these dynamics when studying and monitoring the water levels in these wetland areas.

Based on this analysis, dam construction, climate change, and agricultural impact are among the potential drivers of reduced water levels. Our results indicate that climate change cannot be considered the only threat to Iran's wetlands, with human activities such as dam construction and agriculture also making a critical impact on these habitats. This study creates a baseline assessment and analysis of the ways in which climate change and other human activities may have impacted Iran's wetlands. Continuing to assess Iran's wetlands over time through satellite imagery, dam and agricultural mapping, temperature, and precipitation data can help researchers better understand and assess the complex threats that exist for these important ecosystems over time.

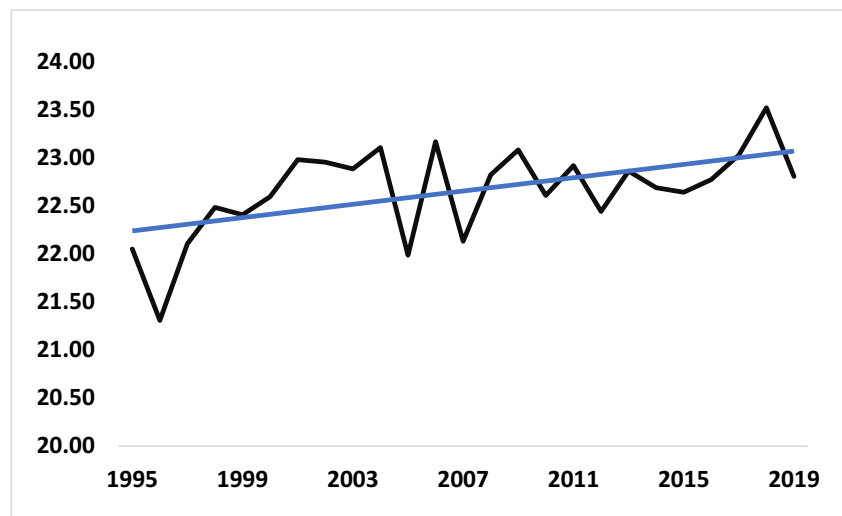
## Appendix

This appendix shows the temperature and precipitation trends of the wetlands whose areas have decreased in 2020.

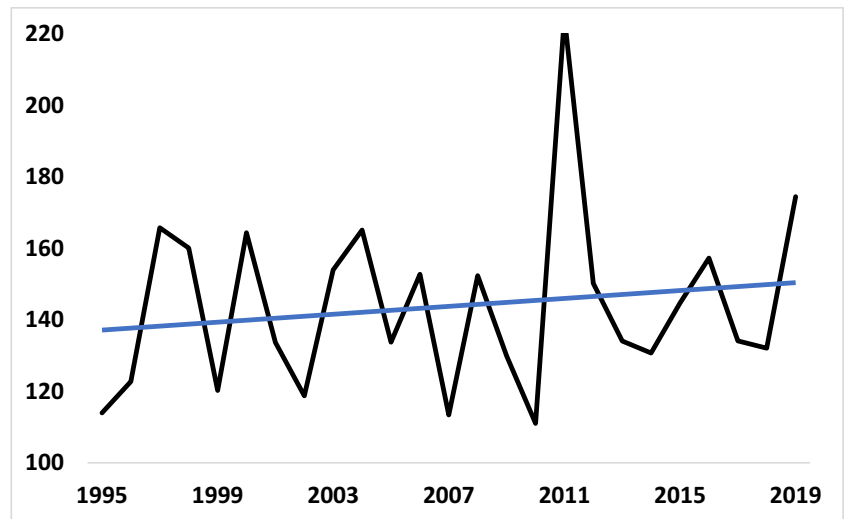
**Fig. 5** Precipitation trend (mm) in Hamon-e-Puzak, South end and Hamon-e-Saberi, and Hamlm-e-Hirmand wetlands between 1995 and 2019



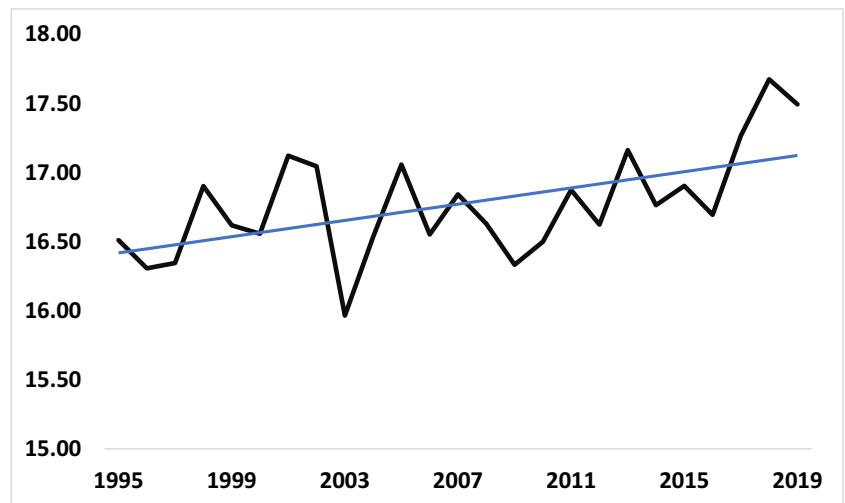
**Fig. 6** Temperature trend (°C) in Hamon-e-Puzak, South end and Hamon-e-Saberi, and Hamlm-e-Hirmand wetlands between 1995 and 2019



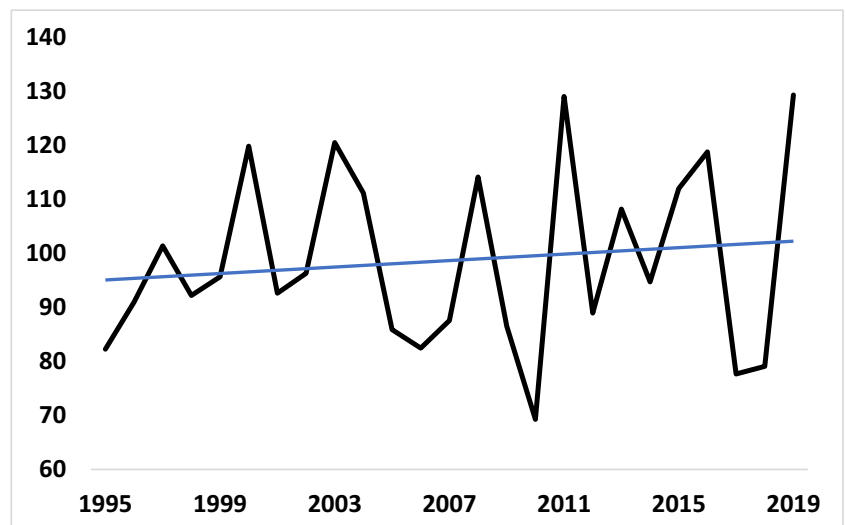
**Fig. 7** Precipitation trend (mm) in Anzali Mordab between 1995 and 2019



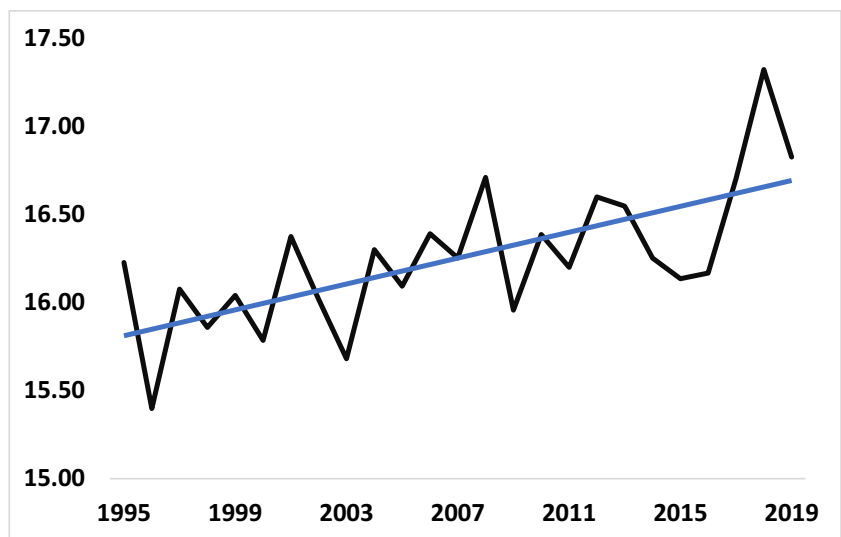
**Fig. 8** Temperature trend (°C) in Anzali Mordab between 1995 and 2019



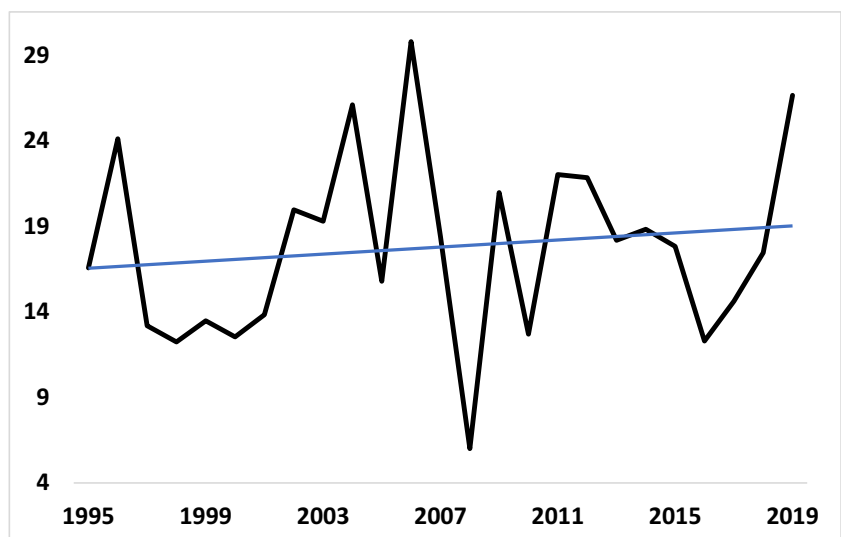
**Fig. 9** Precipitation trend (mm) in Amirkelayeh Lake between 1995 and 2019



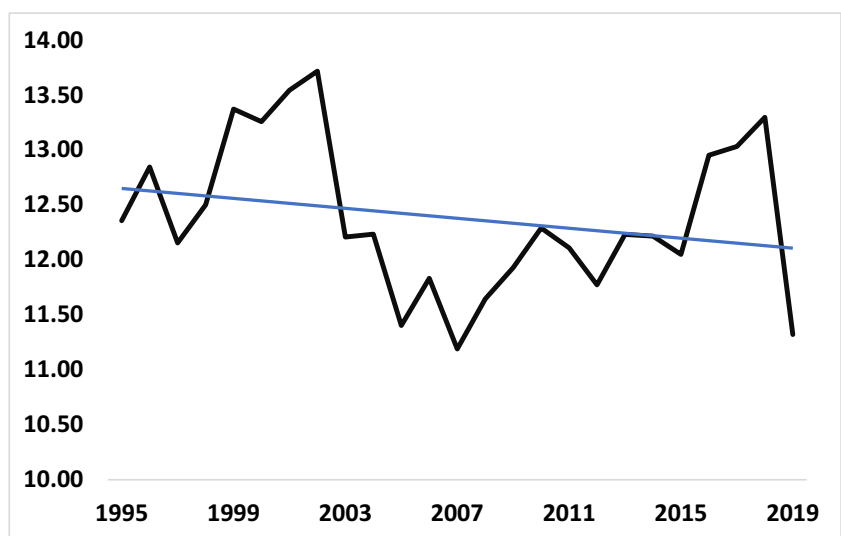
**Fig. 10** Temperature trend (°C) in Amirkelayeh Lake between 1995 and 2019



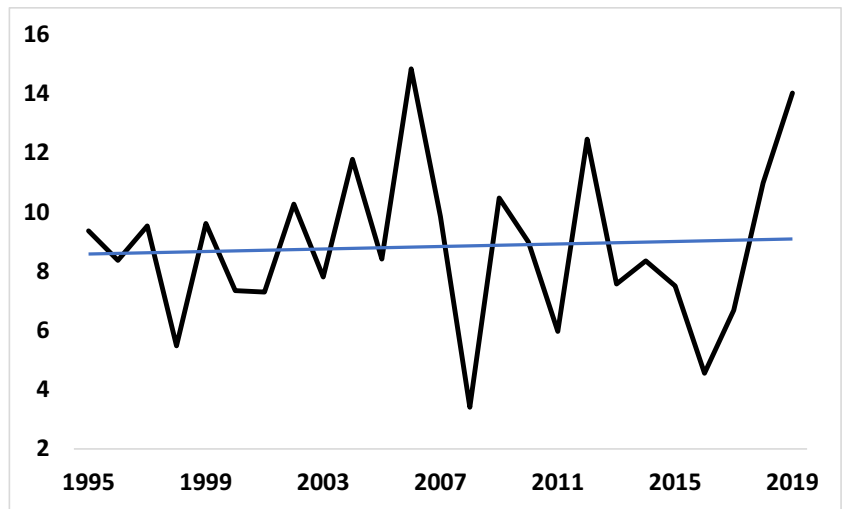
**Fig. 11** Precipitation trend (mm) in Choghakhor Wetland between 1995 and 2019



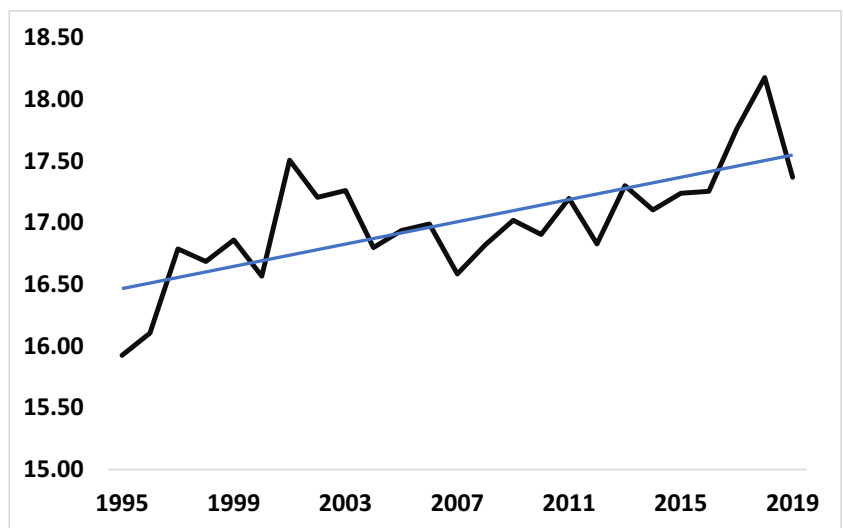
**Fig. 12** Temperature trend (°C) in Choghakhor Wetland between 1995 and 2019



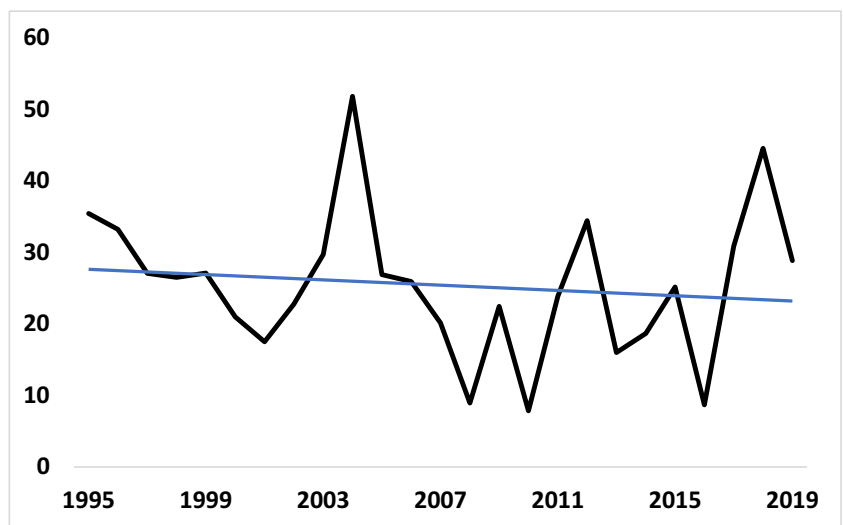
**Fig. 13** Precipitation trend (mm) in Gavkhouni Lake and marshes of the lower Zaindehrud between 1995 and 2019



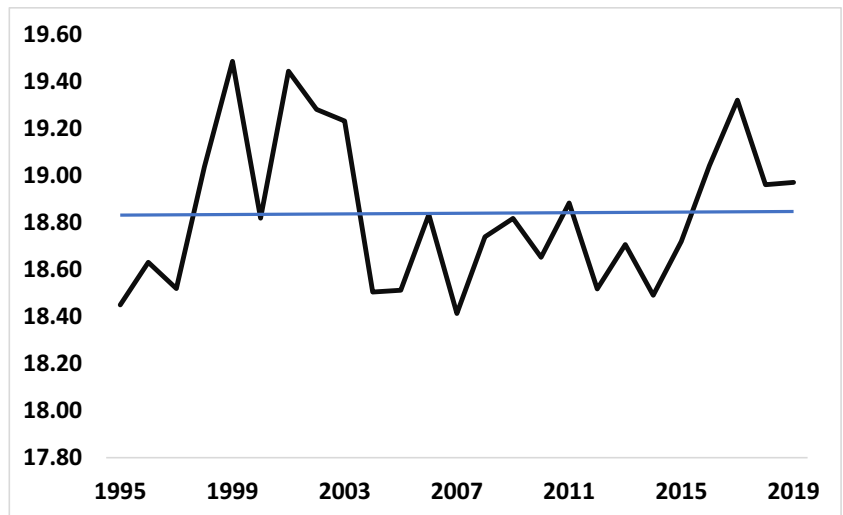
**Fig. 14** Temperature trend (°C) in Gavkhouni Lake and marshes of the lower Zaindehrud between 1995 and 2019



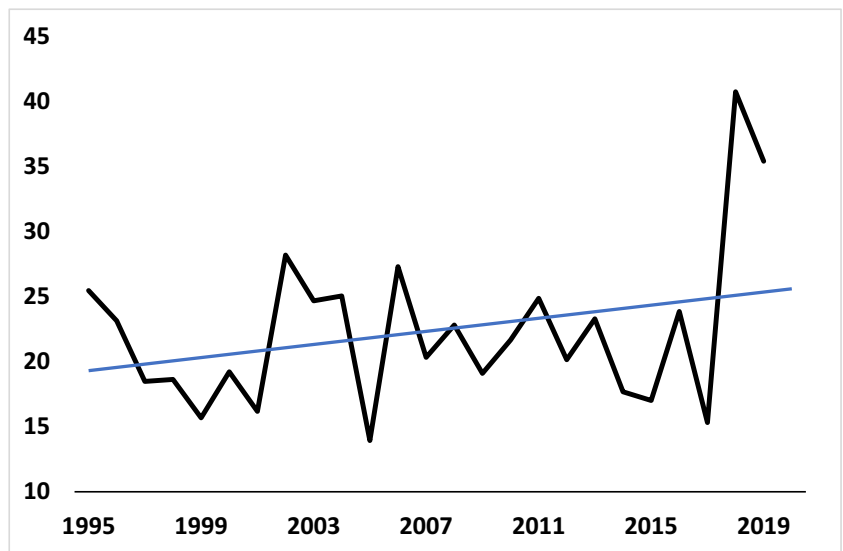
**Fig. 15** Precipitation trend (mm) in Lake Parishan and Dasht-e-Arjan between 1995 and 2019



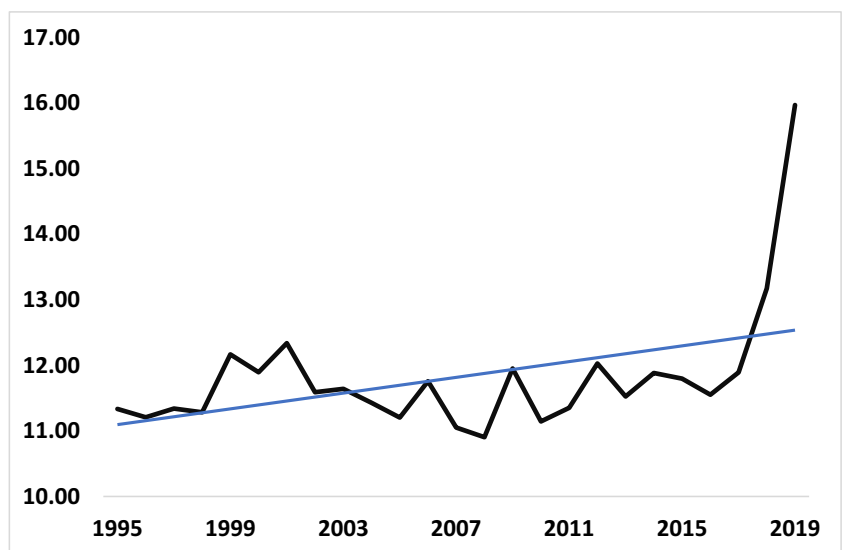
**Fig. 16** Temperature trend (°C) in Lake Parishan and Dasht-e-Arjan between 1995 and 2019



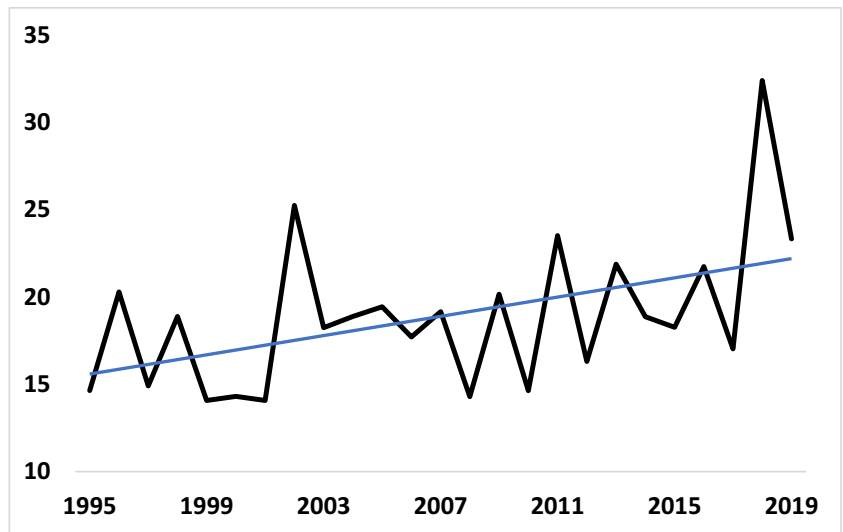
**Fig. 17** Precipitation trend (mm) in Lake Urmia between 1995 and 2019



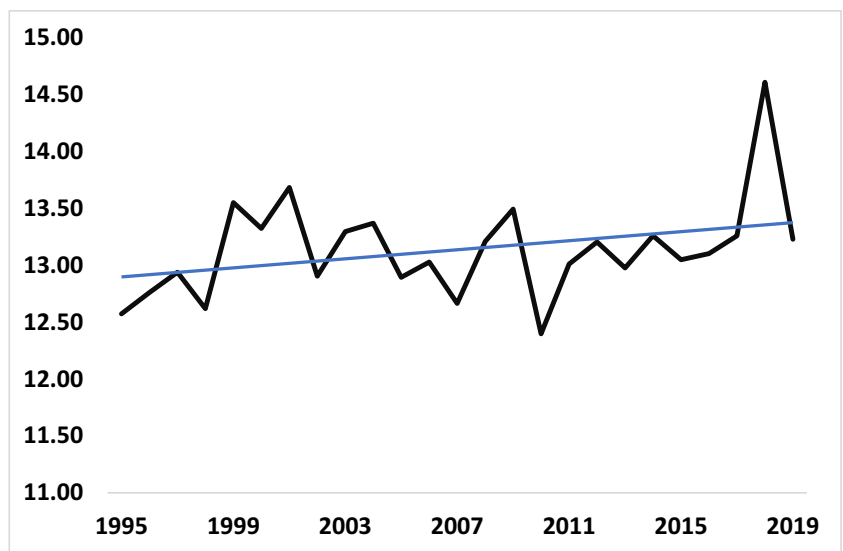
**Fig. 18** Temperature trend (°C) in Lake Urmia between 1995 and 2019



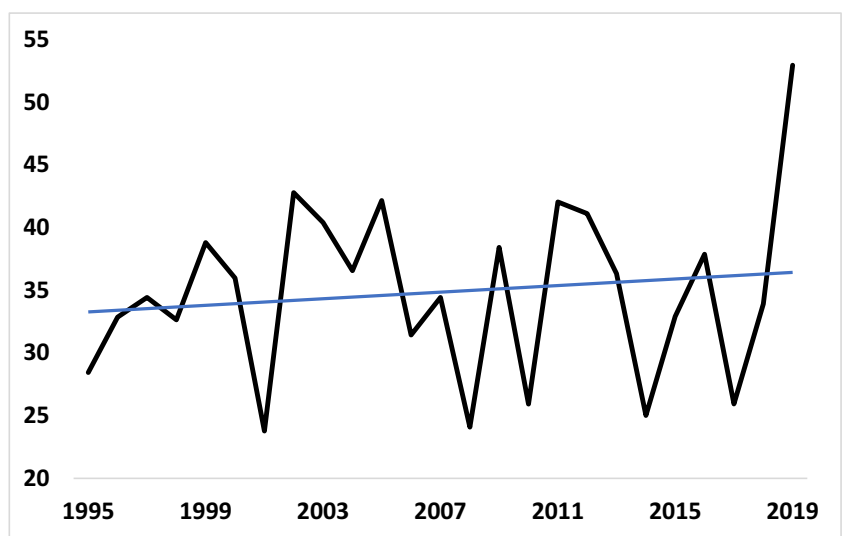
**Fig. 19** Precipitation trend (mm) in Lake Gori between 1995 and 2019



**Fig. 20** Temperature trend (°C) in Lake Gori between 1995 and 2019

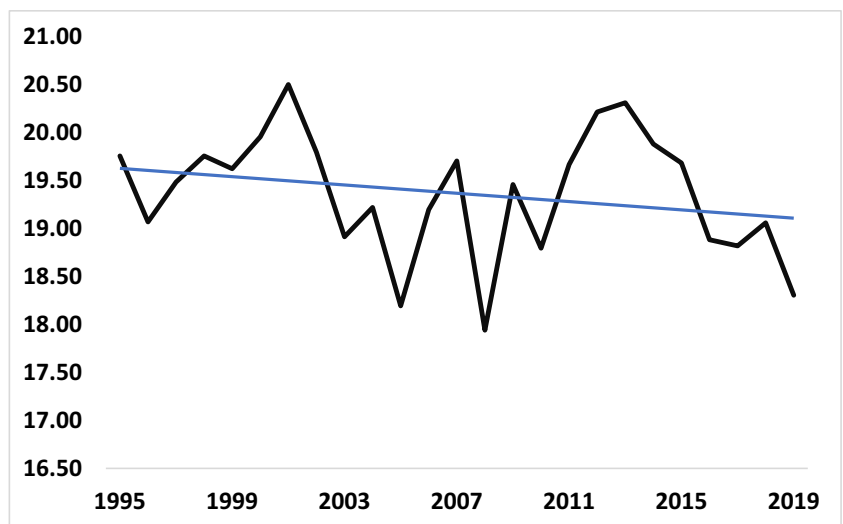


**Fig. 21** Precipitation trend (mm) in Alagol, Ulmagol, and Ajigol Lakes between 1995 and 2019

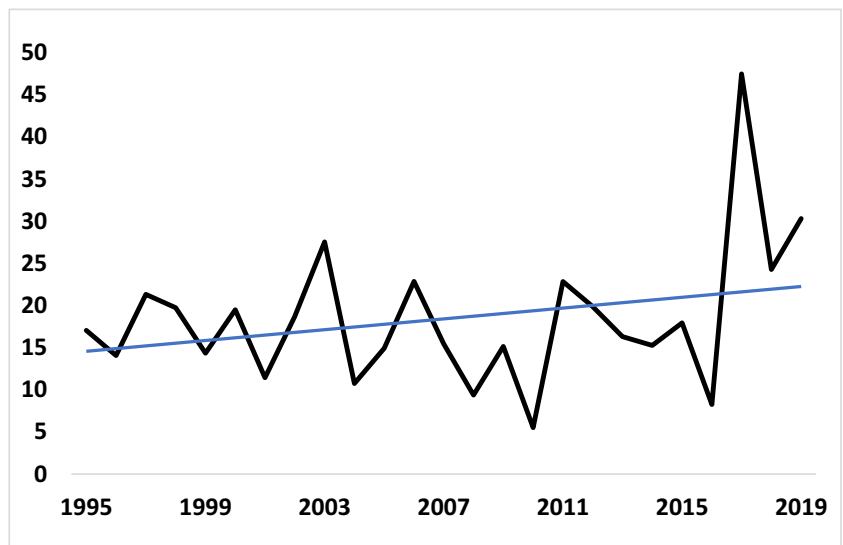




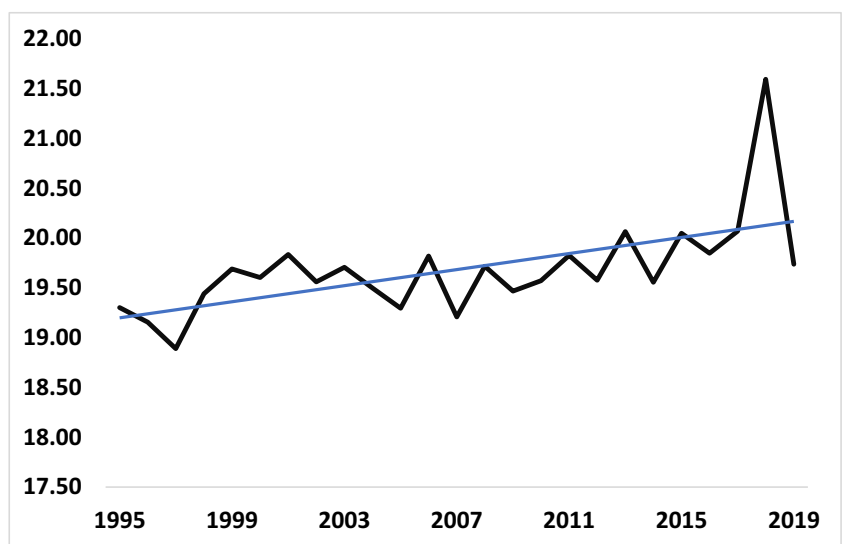
**Fig. 22** Temperature trend (°C) in Alagol, Ulmagol, and Ajjigol Lakes between 1995 and 2019



**Fig. 23** Precipitation trend (mm) in Neyriz Lake and Kamjan Marshes between 1995 and 2019



**Fig. 24** Temperature trend (°C) in Neyriz Lake and Kamjan Marshes between 1995 and 2019



**Data availability** Data are available on request from the authors only based on logical requests.

**Code availability** Not applicable.

## Declarations

**Ethics approval** Not applicable.

**Consent to participate** All authors consent to participate in writing this paper.

**Consent for publication** All authors consent to publish this paper.

**Conflict of interest** The authors declare no competing interests.

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