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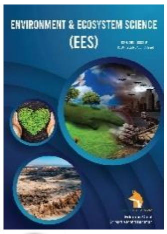

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RESEARCH ARTICLE

DECLINE OF FOREST ECOSYSTEM THROUGH CLIMATE CHANGE: DIEBACK IN PERSIAN OAK (*QUERCUS BRANTII* LINDL.)

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ABSTRACT

Climate change could alter forest disturbances, such as insect outbreaks, invasive species, wildfires, storms, and disease. In the present study, the influence of climate change on the structure and decline of Persian oak in the Zagros forest stands is scrutinized. A regular random sampling with fixed sample plots through two sampling periods was applied in 1998 and 2018. Further, the precipitation, temperature, frost, and relative humidity climatic elements pattern was studied from 1988 to 2018. The cross-sectional of standard-form oak was decreased from 19.2, 23.3, and 24 m^3.ha in the first sampling stage to 12.3, 16.8, 17.8 m^3.ha in the second sampling in Vizhenan, Chelleh, Ghalajeh, respectively. Levene's test for equality of variances and mean comparison findings via an independent t-test showed a significant difference between the compared groups in 1998 and 2018. The Mann-Kendall analysis results of climatic elements showed that the precipitation, frost, and relative humidity decreased, and the temperature increased during the study period. Noticeable stability was perceived in the studied indices in the first decade and partially in the second decade, but there were many fluctuations in the third decade. According to the findings, it can be assumed that climate change and the occurrence of severe drought stresses cause oak trees to suffer from physiological vulnerability.

KEYWORDS

Climatic elements, time series, structural features, Physiological processes, Zagros.

1. INTRODUCTION

Although it is reliable to declare that global mean temperatures are increasing steadily and will continue to rise, the particular amount and timing of heating in various regions is not explicit (Spies et al., 2010; Rogelj et al., 2012; Palik et al., 2020). Even the decrease in seasonal rainfall or the commonness and severity of storms or other atmospheric events varies critically (Bengtsson et al., 2006; Maduako et al., 2016; Buras et al., 2021). Additional uncertainty is how drought will occur in the forthcoming (Abatzoglou and Barbero, 2014). Ascending temperatures and seasonal precipitation transformations result in a primary increase in the frequency and severity of drought worldwide (Allen et al., 2010). However, according to forecasts, there is often unpredictability in the amount, period, and frequency of future droughts (Siwecki and Ufnalsk, 1998). Many of these are results of regional distinctions in vegetation and landscape (Wang et al., 2015). Even on a smaller scale, complex local landscape and habitat micro-changeability critically influence the occurrence of climate change as restructuring events and drought (Denman et al., 2012; Asakereh et al., 2021). One of the most remarkable settings affected by these changes resulting from high sensitivity is the forest ecosystems.

Alterations in climate settings can concern disturbance regimes of woodland environments (Seidl et al., 2017). Disturbances are a customary component of ecosystem improvement and preserve reorganized the feasible routes of change at uneven intervals. Abiotic disturbances such as the size and frequency of wildfires, forest regression, and storm events have been related to climate change, even though the abrupt instrumental relationships are not yet verified (Allen et al., 2010; Gardiner et al., 2010). Sharper is the association between climate change and biotic disturbances. As biological procedures are temperature measured, pests and pathogens are expected to alter their habitat extents and are developing destructive in regions where they have not reached crucial inhabitants densities previously (Battisti et al., 2005; Marini et al., 2012; Netherer and Schopf, 2010). There is durable substantiation that some latest epidemics of bark beetles and defoliating insects are related to climate change, and these are having enormous impressions on ecosystems as well as on forest insect groups (Kurz et al. 2008; Pureswaran et al., 2018).

Oak decline (OD) is a complex abiotic disturbance that has arisen in some of the world's oak forests (Thomas, 2008; Denman et al., 2014; Gentilesca et al., 2017). Similarly, the oak decline lately has significantly affected the Zagros forest ecosystem (Jafari et al., 2021). These forests have been in decline for about two decades, and the impacts of this crisis are visible in diverse areas (Kooh et al., 2018). Based on the latest announcements, between 2009 and 2014, approximately 350,000 hectares, or on the other hand 25% of these forests were polluted (Ahmadi et al., 2016 **;**Jafari et al., 2021). In this regard, we can point to the degeneration occurring in vast areas of Persian oak forests (*Quercus brantii* Lindl.) in the South Zagros region (Ahmadi et al., 2016). The oak decline (OD) is lately increasing and has caused concern among foresters and relevant administrators.

Countless studies have been accomplished ever since on the effect of various factors on the severity of oak tree decline in the Zagros vegetation area (Attarod et al., 2015; Fallah and Haidari, 2018; Taghi, 2019; Attarod et al., 2021; Safari et al., 2022). A group researchers reported no significant difference in the drought severity between the northern and southern slopes (Zarafshar et al., 2020). However, the moisture reduction factor in the root rhizosphere recreates the primary function in the prevalence of

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oak tree decline (OTD). The study's results on the main factors affecting the drought of Persian oak attributed the highest importance to drought and climate change (0.289) while the lowest priority to the quantitative and qualitative characteristics of the tree and its forestry difference (0.097). Other criteria include pests and diseases (0.194), human and livestock factors (0.192), air pollution (0.123), and habitat quality (0.55), respectively (Karmian and Mirzaei, 2020).

By overlying the forest degradation map with climatic characteristics, there exhibit that the most imperative causes that have a significant correlation with forest degradation classes consist of rainfall (0.779), air temperature (0.776), relative humidity (0.602), and reference evapotranspiration (0.670), respectively (Attarod et al., 2015). Predicting the effect of climate change on the Persian oak species revealed that the annual rainfall and the mean temperature of the driest season retain the highest importance in determining the habitat suitability of the species, respectively. Predicting the effect of climate change under the RCP 4.5 scenario showed that the area of the Persian oak habitat will decrease by 35.7% in 2050 (Heydarian et al., 2017).

The SPI index consequences in Lorestan indicated that the forest cover area with a specified greenery threshold is susceptible to drought. As a result, for every 0.1 unit change in the SPI index, the forest-covered area of 14880 ha will alter in the same direction (Alirezaee et al., 2019). Ecological causes of oak decline (OD) in Iran's forests showed that decreasing rainfall and increasing climatic parameters of air temperature, wind speed, sunlight, evaporation, transpiration, and dust increased the probability of tree mortality (Pourhashemi and Sadeghi, 2020). Analyzing the impact of rainfall instabilities on the forest decline in the Zagros vegetation zone and determining the appearance of rainfall fluxes can be an accelerating characteristic in the occurrence and development of the Zagros forest decline in Lorestan and Ilam provinces (Attarod et al., 2021).

In the broadleaf forests of the United States, if droughts become more frequent or severe, the oak decline will increase in species such as *Quercus rubra*, *Q. velutina*, *Q. coccinea*, and *Q. alba.* Therefore, the increase in small and large fuels resulting in tree mortality raises the threat of forest fires (Vose et al., 2012). The AOD is characterized by four key features such as weeping patches more-or-less vertically aligned on oak tree trunks; cracks between bark plates from which dark fluid seeps; inner bark necrosis, and the presence (in .90 percent of cases) of larval galleries of the oak buprestid, *Agrilus biguttatus*, on the phloem–sapwood interface (Debman et al., 2014).

Another study concentrates on the impact of climate change on forest ecosystems. Climate change, directly and indirectly, alters forest ecosystems. Rising temperatures directly affect physiological processes such as photosynthesis rate and respiratory mechanisms while indirectly increasing the infection hazard. Climate change alters disturbance regimes that affect the carbon cycle, forest structure, species composition, and forestland ecosystem function changes (Gebeyehu and Hirpo, 2019).

An additional analysis reported extensive changes in forest cover across Europe. There are expected further contrasts in response to the foreseen changes in drought and windstorm regimes. The forest canopy contains a dynamic relationship between the atmosphere and the earth's surface, as a result, canopy-dwelling insect communities are intensely influenced by modifications in reaction to the direct and indirect climate change effects (Sallé et al., 2021).

Studies analysis reveals that conducted studies on this subject are mainly modeled based on meteorological and atmospheric data. There is a quantitative and qualitative inventory of Persian oak in unforeseen periods, so there is an information gap. Therefore, in the present study, the influence of climate change on the structure and Persian oak decline in the Zagros forest stands in western Iran is scrutinized through meteorological data and the quantitative and qualitative sampling of Persian oak in the permanent sample plots (PSP).

2. Materials and Methods

2.1 Experiment Environments

The Gilan-e Gharb basin is one of the western and border areas of the Kermanshah region, which includes an area of 224,500 hectares and is the second-largest municipality in the section. This area is adjacent to Sarpol-e Zahab and Islamabad-e Gharb regions from the north, the Ivan-e Gharb area in Ilam province, and the Iraq border from the south, the Qasr-e Shirin from the west, and the Sarableh in Ilam province from the east. The height of the Gilan-e Gharb basin ranges between 250 (the Somar region) and 2355 M.A.S.L. (the Kachel peak). This height difference has resulted in three different warm, temperate, and cold circumstances in the zone. The Gilan-e Gharb location extends from 33°41'24" to 34°25'43" north latitude and 45°35'39” to 45°48'58" east longitude. Forest resources in this area are part of the Zagros ecosystem, whose dominant species comprises the Persian oak.

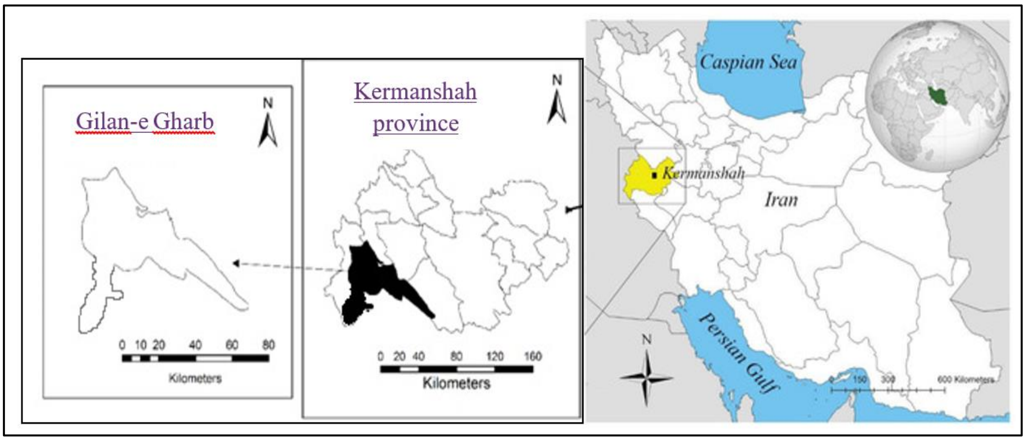

Figure 1: Location of the study area in Southwest Asia

2.2 Experiment Scheme

There applied two samples in 1998 and 2018 through a systematic random sampling model with fixed sample plots to conduct this research. During this process, locating the measured sample plots in the sampling 2018 on the same sample plots in the sampling 1998 was performed with the fixed sampling plots approach (FSPA). The first sampling period was accomplished before the oak decline (OD) in 1998. The pursuit was to examine the frequency, stock, and quantitative and qualitative situation of whole species in the habitat, specifically the Persian oak. Their first sampling period was conducted by a systematic random procedure in a distance-azimuth method. There were determined dimensions of the sampling grid as 150 x 200 meters, and the area of each sample plot was considered 0.2 hectares (2000 m^2); (Zobeiri, 2005). In that period, 100, 125, and 115 sample plots with a distance of 1000 m by 1000 m from each other were appraised in Vizhenan, Balaleh, and Ghalajeh, respectively.

Preferably, there was a prepared forest cover map during the sampling period in 2018. Then the whole area of the study regions was divided into comparable subdivisions. The existing field was divided into small squares with dimensions of 150 × 200 meters. There were established sample plots at the square's vertices (line intersections), and after that were fulfilled the measurement procedures. There were applied geographic position systems (GPS) and geographical coordinates to refer to the exact location of these plots. Afterward was gathered the preferred data in the mentioned area. Eventually, the sample plots through the distance-azimuth procedure, environmental cues, and consultation with participants in the first sampling stage.

Accumulated measurements for each sample plot included vegetative forms such as standard or coppice tree, the diameter at breast height (DBH) for the standard tree, diameter at the collar height (DCH) for coppice tree, tree length, tree condition (alive and healthy or dead), and

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decay ratio (1, 2, 3, 4 (stand wide-ranging decayed), and 5 (downed extremely decomposed)). Classification of deciduous trees' health included: 1. A live and healthy tree, standing, hardwood, hard skin, green top; 2. A living tree, dead top, upstanding, hardwood, dead crown; 3. upright tree, softwood, broken crown; 4. Snag, released wood, without crown; 5. Fallen dead wood, fine and coarse woody debris, log, loosed wood, and softwood (Aghajani et al., 2017).

The quality of trees as defined in the first sampling period (before the oak decline crisis) in four quality rates for all trees. 1. Smooth trunk, without limbs, without knots, without complexity, and free of decay. 2. Has the characteristics same as type 1 except that sort 2 includes three nodes or three branches. 3. The number of nodes and branches is more, and there is more complexity. 4. Decay (dryness) and the number of branches is such that it has become a dead tree. There were obtained sampling data of the first period before the outbreak of oak decline in the Zagros, and decay was one of the qualitative classes.

2.3 Climatic Elements

For this analysis, the Gilan-e Gharb synoptic station with an altitude of approximately 800 m.a.s.l. was considered. Four climatic elements, such as annual rainfall, temperature, frost, and relative humidity, were analyzed from 1988 to 2018.

2.4 Questionnaire

There, open or unstructured interviews to gather data were used. In this approach, there are no standardized queries and no predetermined responses. The interviewer explores the respondent's mind comprehensively on predefined topics. The type of interview that the researcher prefers relies on the research objectives and the informant's attributes. Since the pursuit of the present study was to examine climate change over the past decades, it was decided to dissect the issue from distinct perspectives by releasing informants, who were typically elderly and experienced individuals. Respondents could comment and narrate climate change in the study area in any way they wished. It should be noted that the interviews were conducted individually and in person, and all conversations were recorded and then transcribed. At this step, thoughts were assembled from 300 diverse elderlies with mental health at various sites throughout the basin.

2.5 Statistical Analysis

The Mann-Kendall nonparametric test was preferably formed by Mann and then developed by Kendall based on data rankings over a time series (Mann, 1945; Kendall, 1975). The cited method is widely performed in the hydrological and meteorological series analysis. One of the advantages of this procedure is its appropriateness for time series that do not observe a precise statistical distribution. The low effectiveness of this method from the boundary values observed in some time series is another advantage of this approach. The null hypothesis of this test indicates that the trend in the data series is haphazard and does not exist. The approval of hypothesis one (null hypothesis) indicates the existence of tendencies in the data series. This test was proposed by the World Meteorological Organization in 1988 and has been applied repeatedly and in various cases to study the significance of climate trends.

In the Mann-Kendall graph method, if the sequence's U and U' are plotted based on i, in a significant state, the two diagrams intersect at the starting point outside the ±1.96 range and move in opposite directions. This collision point is called a jump. Whereas if there is no trend, the U and U' sequences will move virtually in parallel or with multiple collisions so as not to reverse direction. There is a random series in some cases which is -96 <U <+1.96, so no specific trend can be imagined for it. While U> +1.96 indicates a positive trend and U <-1.96 indicates a negative tendency.

3. Results

3.1 Abundance

The mean frequency of Persian oak is nearly 79.5% in the first sampling period in diverse regions, while the mean rate of this species is relatively 67.4% in the second sampling period in different sites. The highest frequency consists of the Vizhenan region which includes 3.82% and 1.76% in the 1998 and 2018 sampling periods, respectively (Table 1).

Table 1: Comparison of the Persian Oak Frequency In Different Sites In 1998 And 2018 Samplings

Sites	1998			2018		
	N.plot	N.ha	%	N.plot	N.ha	%
Vizhenan	49	245	82.3	45.2	226	76.1
Chelleh	45.4	227	76.4	41.7	208.6	70.2
Ghalajeh	42.6	218.1	73.4	40.8	204.1	68.7
Mean	46±0.52	230±0.35	77.3	42.6±0.16	212.9±0.33	71.7

3.2 Volume

The mean stock displays that the cross-sectional area in standard and coppice forms of Persian oak included 15.7 ± 0.22 and 5.95 ± 0.15 m^2. ha in the first period, respectively. It comprised 10.4 ± 0.11 and 4.86 ± 0.08 m^2. ha in the second period, respectively (Table 2).

The highest stock (18.1 ± 0.32 m^2. ha) for the standard form consists of the Ghalajeh site in 1998. The most-heightened stock portion (6.8 ± 0.21 m^2. ha) for the coppice form retains the Vizhenan area in 1998.

3.3 Quality and Health Situation

The findings illustrate that 84.9% of Persian oak trees were healthy while 15.1% were defective in the 1998 sampling. Around 27.8% of Persian oak trees were healthy, while 72.2% of the trees were infected and dead in the 2018 sampling (Figure 2).

The highest rates of healthy oak trees in the Ghalajeh habitat include 92.4% and 31.8% in 1998 and 2018 samplings, respectively. The proportion of decayed and infected trees in 1998 and 2018 samplings comprising the Vizhenan habitat is 27.4% and 78.8%, respectively (Figure 2).

The frequency of degradation type in the Persian oak species shows that the mean highest rate in various sites is virtually 24%, it contains declining class 3 in 2018. On the contrary, the lowest mean frequency of deterioration occurs in class 4, around 14.5% (Figure 3).

Table 2: Comparison of Persian Oak Stock on Various Habitats in 1998 And 2018 Samplings

Sites		Basal area 1998		Basal area 2018		(%)	(%)
		plot	Ha	Plot	Ha	1998	2018
Vizhenan	High-form	2.46±0.05	12.3±0.32	1.44±0.5	7.2±0.2	64.4	58.5
	Coppice form	1.36±0.04	6.8±0.21	1.02±0.10	5.1±0.16	35.6	41.5
Chelleh	High-form	3.36±0.05	16.8±0.17	2.28±0.16	11.4±0.14	72.1	67.85
	Coppice form	1.3±0.03	6.5±0.15	1.08±0.05	5.4±0.22	27.9	32.1
Ghalajeh	High-form	3.62±0.06	18.1±0.32	2.58±0.15	12.9±0.35	79.9	75.9
	Coppice form	0.92±0.02	4.6±0.12	0.82±0.07	4.1±0.19	20.3	24.1
Mean	High-form	3.14±0.1	15.7±0.22	2.08±0.3	10.4±0.11	72.5	68.15
	Coppice form	1.19±0.05	5.95±0.15	0.97±0.03	4.86±0.08	27.5	31.85

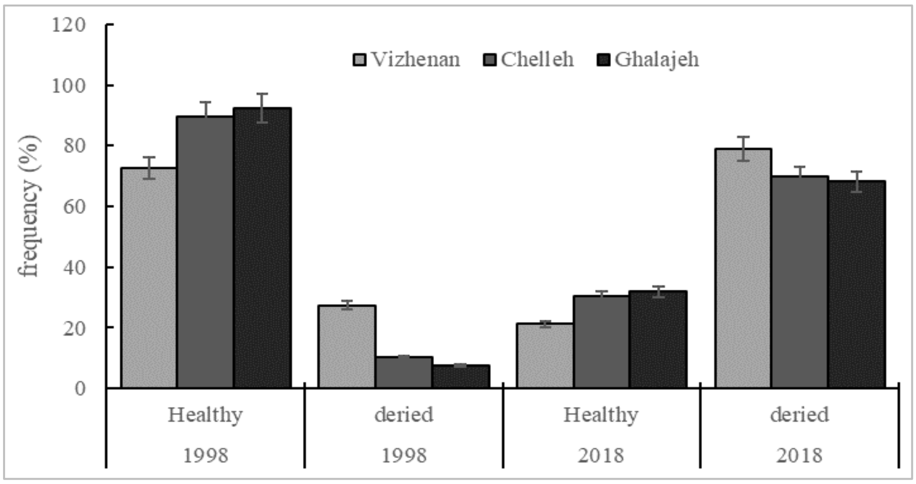


Figure 1: Health status of the Persian oak trees in 1998 and 2018 sampling periods

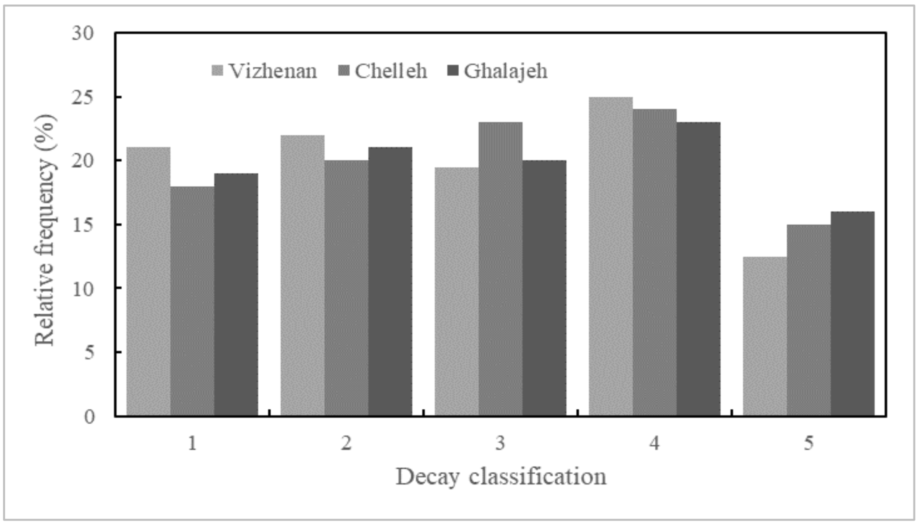


Figure 2: The frequency of degradation category in the Persian oak species in various habitats in 2018

The highest mean abundance (60%) of the Persian oak tree quality includes healthy individuals in 1998, while the lowest moderate occurrence (6.9%) of Persian oak tree quality contains dead and decayed stems. The recurrence of healthy Persian oak trees (69.1%) includes the Ghalajeh site in 1998. The highest prevalence of decayed and dried Persian oak trees (11.5%) accounted for the Vizhenan habitat in 1998 (Figure 4).

Levene's test for equality of variances and mean comparison results employing an independent t-test showed a significant difference between the compared groups in 1998 and 2018 in the Cheleh, Ghalajeh, and Vizhenan sites, respectively (Table 3).

3.4 Climatic Elements

3.4.1 Perception

For three decades, the highest annual rainfall was 684.4 mm. yr, which occurred in 1990, while the lowest annual rainfall includes 198.3 mm. yr, which happened in 1999 (Figure 5). An annual rainfall comparison in the years in the studied decades shows that the annual rainfall during the first decade (1988-1998) was more and more regular than in the other decades. The lowest and the most irregularity in yearly precipitation occurred in the third decade (1998-2018); (Figure 5).

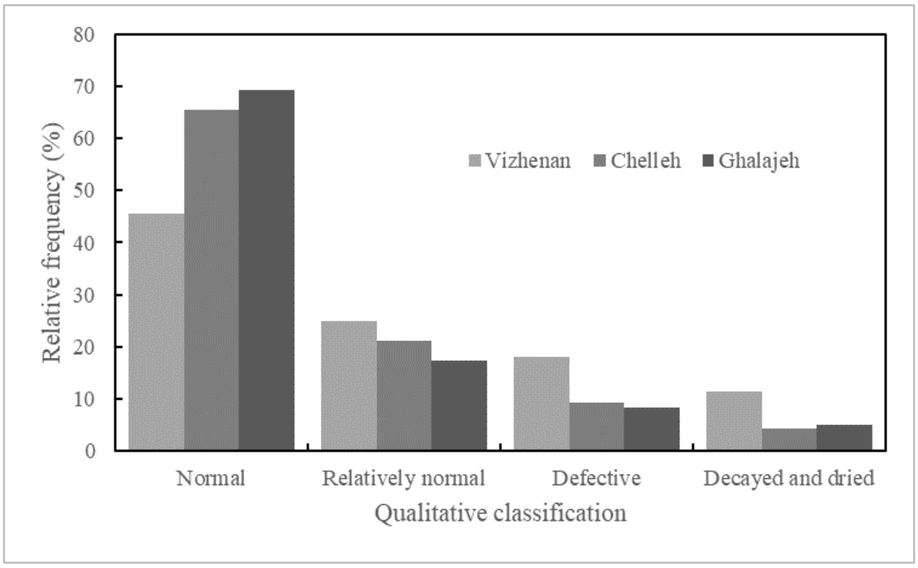


Figure 3: The frequency of degradation category in the Persian oak species in various habitats in 1998

Table 3: Independent Samples Test in 1998 and 2018 in Cheleh, Ghalajeh, and Vizhenan Habitats

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Chelleh	Equal variances assumed	10.12	0.002	2.33	248	0.02	0.74	0.31	0.11	1.37
	Equal variances not assumed			2.33	212.90	0.02	0.74	0.31	0.11	1.37
Vizhenan	Equal variances assumed	43.56	0.000	4.66	196	0.00	1.47	0.31	0.85	2.09
	Equal variances not assumed			5.53	189.07	0.00	1.47	0.26	0.95	2.00
Ghalajeh	Equal variances assumed	86.01	0.000	5.83	226	0.00	2.11	0.36	1.40	2.83
	Equal variances not assumed			6.376	136.72	0.00	2.11	0.33	1.46	2.77

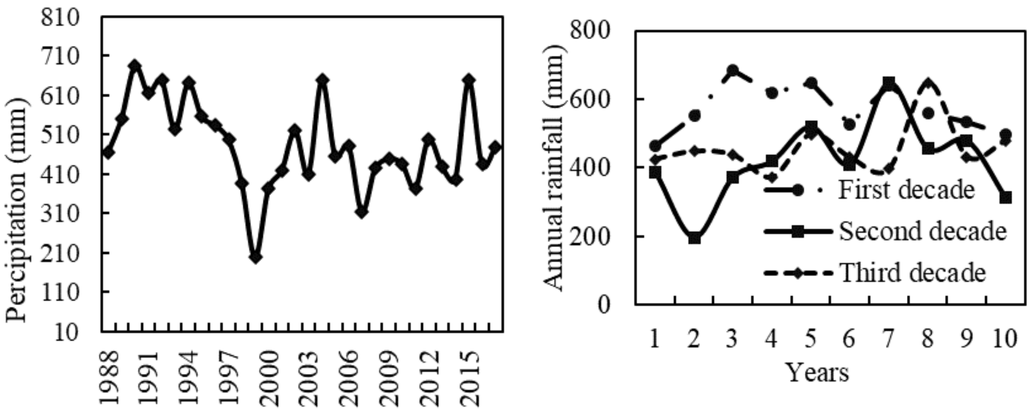


Figure 5: Annual rainfall in the study period (left) and year comparison in the three decades (right)

3.4.2 Temperature

The mean temperature per year during three decades showed that the highest include 22.2°C, which occurred in 1998, while the lowest comprise 19.3°C, which happened in 1999 (Figure 6). A mean annual temperature comparison in the three decades studied shows that the annual temperature during the second decade (1998-2008) was higher than the 1988-1998 and 2008-2018 decades and fluctuated. The lowest and most irregular mean annual temperature in the year includes the first half of the third decade (1998-2018). In the second half of this decade, the temperature reaches its highest value (Figure 6). The first decade has the most stable state possible (Figure 6).

3.4.3 Relative Humidity

The mean annual relative humidity showed that its maximum amount comprises approximately 53% between 1991 and 1998, while the lowest annual relative humidity, with 34%, includes 2005 within three decades (Figure 7).

An annual relative humidity comparison shows that the amount of annual relative humidity in the years of the first decade (1988-1998) was higher than in the 1998-2007 and 2008-2018 decades. The lowest and most irregular annual relative humidity includes the 1998-2007 decade of the studied period (Figure 7). At the beginning of the third decade, the monthly relative humidity was higher than in the second decade. In the last two years of this decade, the relative humidity decreased to the lowest possible level (Figure 7).

3.4.4 Frosty Days

The number of annual frost days during whole decades showed that the maximum number of yearly frost days was 35 days irregularly in 1992, while in 1998 and 2008, the frosty days' frequency was zero (Figure 8). The frequency of glacial days per year comparison shows that the annual glacial day's abundance in the 1987-1997 decade was higher than the other decades and had a decreasing tendency. The lowest and most atypical annual glacial days commonness included the 1998-2007 and 2008-2018 decades in the study period (Figure 8).

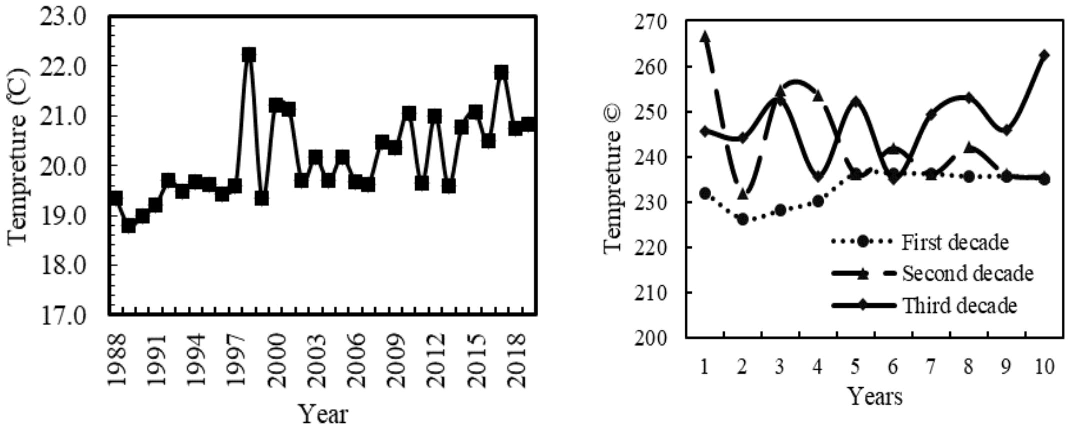


Figure 6: Annual temperature in the study period (right) and comparison of annual temperature in the three studied decades (left)

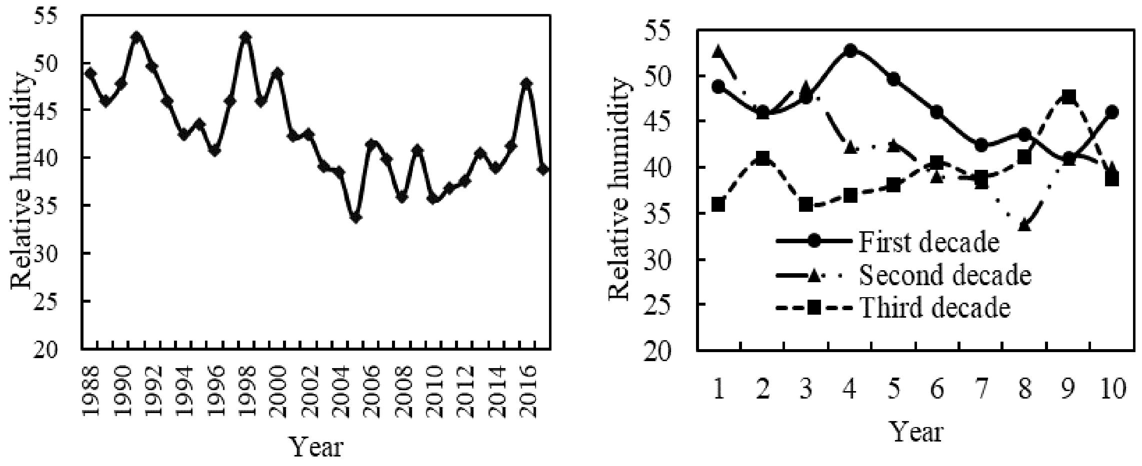


Figure 7: Annual relative humidity in the study period (right) and comparison of annual relative humidity in the three decades (left)

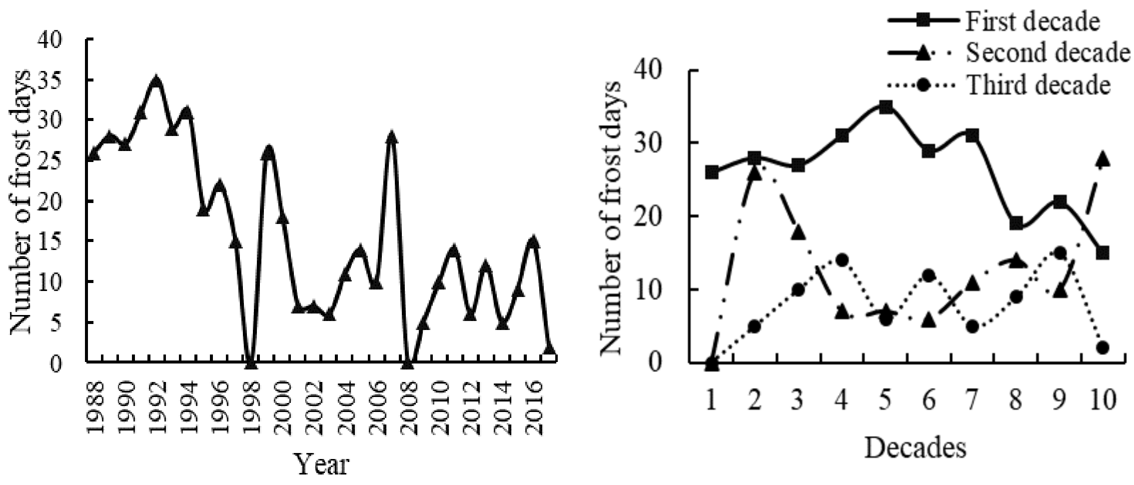


Figure 8: Number of annual frost days in the studied time period (right) and comparison of the mean number of annual frost days in three decades (left)

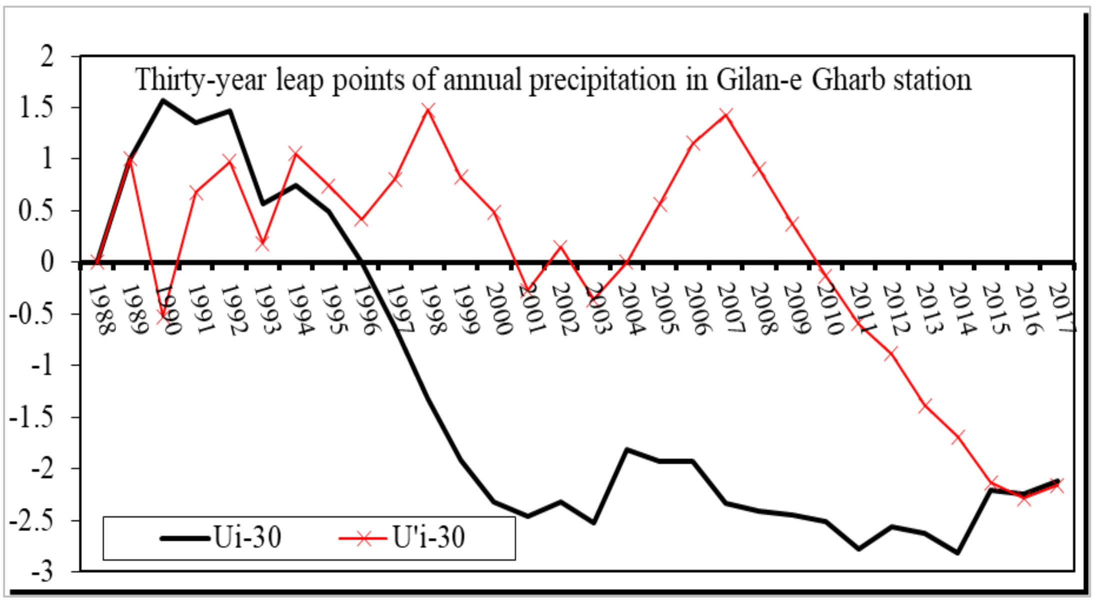
3.4.5 Mann-Kendall test (M-K)

U and U' sequences to determine 30-year jump points involving the non-parametric Mann-Kendall test based on I describe a negative trend for elements such as precipitation, relative humidity, and frost while representing a positive gradient pattern for temperature (Figure 9).

3.5 The Most Important Matters Resulting From Climate Change

Generally, in this study, in the section on climate change in the forests, the first meanings extracted from the interviews are concepts. The categorization of these concepts included sub-codes and principal codes. As a result of the extracted concept's magnitude, are presented the results related to the notions with the substantial and sub-code in table 4.

The most substantial issues resulting from climate change are presented in several main knowledge fields. The most important of these include increasing temperature, decreasing rainfall, decreasing cold weather, increasing the length of the growing season, and drying of some tree species such as Persian oak (Table 4).



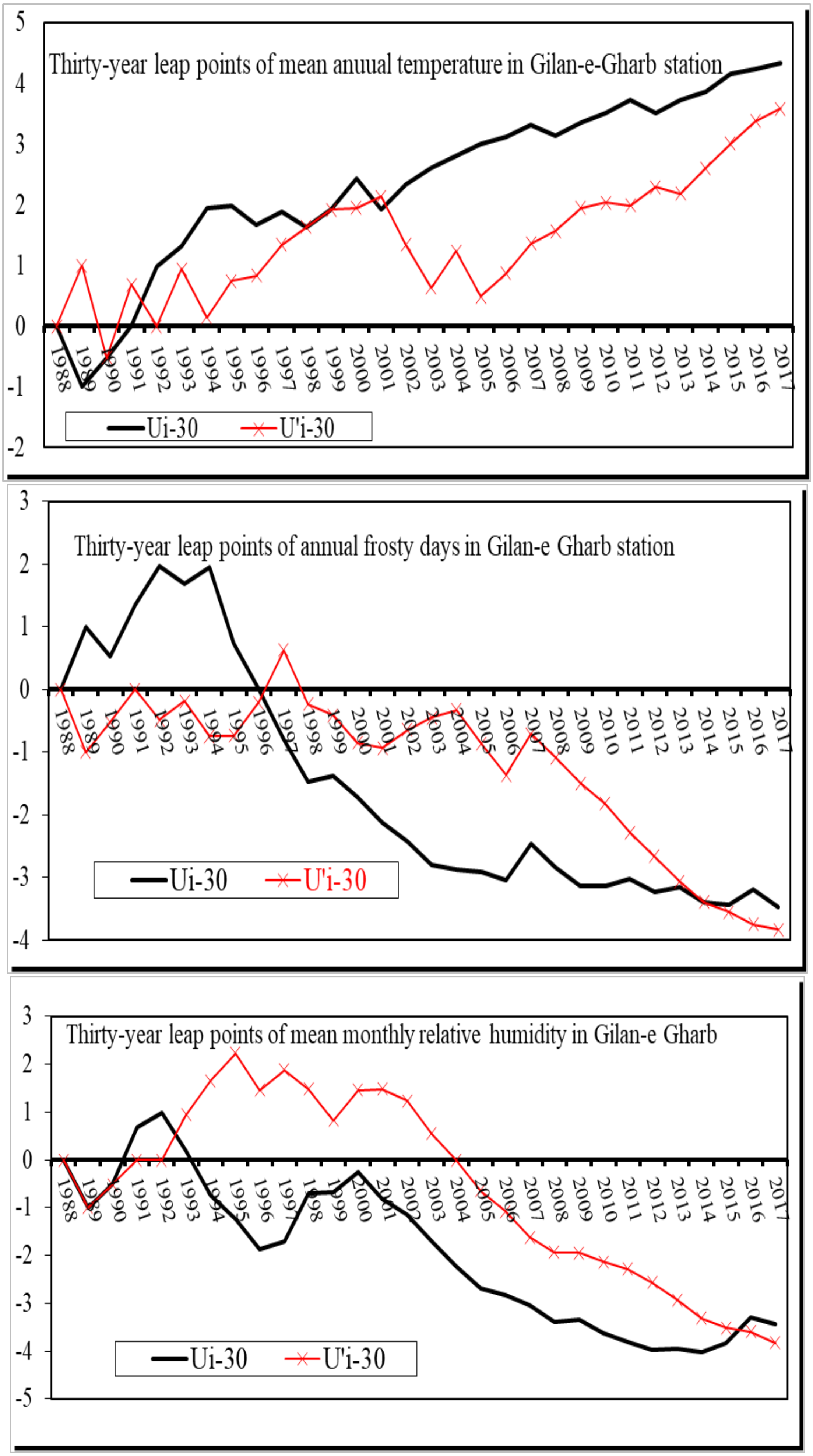


Figure 9: Man-Kendall test diagram for precipitation, temperature, relative humidity and frost over a period of 30 years.

Table 4: Summary of the Most Important Cases of Climate Change in the Study Area

row	Concepts	Sub-code	The main code
1	-Rising temperature -Increasing the number of fires in the region	-Temperature rise -Increasing the number and intensity of fires	-Temperature rise and its consequences
	-Increasing the amount of atmospheric dust -Increasing hot winds in summer	-Increased atmospheric dust	
2	Decreased rainfall Increased drought	-Reduction of precipitation	-Reduction of precipitation and its consequences
	-Reduce snowfall -Reduction and drying of permanent and seasonal river water -Increasing floods Severe fluctuations in	-Reduction of water currents	
	-Atmospheric events -Increase in showers and decrease in precipitation	-Severe fluctuations in atmospheric events	
3	-Reduce cold weather and frost in the cold season of the year -Reducing the duration of cold air fronts -Milder weather in cold seasons	-Reduce cold weather	-Reduction of air coldness and instability of cold atmospheric currents
	-Seen several seasons in one day	-Sometimes the feeling of experiencing several seasons in just one day	
4	-Increase the length of the growing season -Flowering of some tree species in mid-February	-Increasing the growth season	-Increasing the growth season and its consequences
	-Rising late frosts	-Increased late spring frosts	
5	-Decline of some plant species such as oak	Decline of some plant species such as oak	-Mortality and loss of some plant species such as oak
	-Continuation of the insect cycle in the cold season of the year -Continued activity of cold-blooded animals and reptiles in the cold season of the year -Increased pests and diseases in	-Impact on the life cycle of some insects and the continuation of cold-blooded reptiles and animals in the cold season	
	-plant species -Fruitlessness of some garden species such as walnuts	-Increasing the prevalence of pests and diseases in plant species	

3.5 The Most Important Matters Resulting From Climate Change

Generally, in this study, in the section on climate change in the forests, the first meanings extracted from the interviews are concepts. The categorization of these concepts included sub-codes and principal codes. As a result of the extracted concept's magnitude, are presented the results related to the notions with the substantial and sub-code in table 4.

The most substantial issues resulting from climate change are presented in several main knowledge fields. The most important of these include increasing temperature, decreasing rainfall, decreasing cold weather, increasing the length of the growing season, and drying of some tree species such as Persian oak (Table 4).

4. Discussion

Zagros oak forests supposedly appeared approximately 5500 years ago and reached the climax condition (Wright et al., 1967). These forests are mountainous and semi-arid, and one of their ecological requirements is the need for the cold season (Ghaibi et al., 2019). Diverse oaks species are somewhat susceptible to climate change, while in general, the Fagaceae genus includes high ecological compatibility and tolerance. They can resist temperature and rainfall instabilities within the range of -31 to +45°C and 250 to 1000 mm, respectively (Pourhashemi and Sadeghi, 2020). However, the considerably suitable oak habitat contains areas with rainfall of 350 to 750 mm. Based on climatic data; the surveyed habitats are likely to have the mentioned characteristics in the recent past (Afshar et al., 2010).

The findings of climatic elements exhibit that precipitation, frost, and relative humidity during the research period have an undoubted negative pattern, and their frequency and amount have reduced. Typically, the annual precipitation in the study period contained somewhat 480 mm, which during the first decade of rainfall had long-lasting stability, ordering, and distribution. However, there exist many irregularities and fluctuations in precipitation in the second and third decades. There exists a comparable condition for annual relative humidity and frosty days of the year. In contrast to the other three components, what has been observed for temperature displays an increasing movement over three decades. The mean annual temperature in the first decade was lower, and its oscillations were less than in the other two decades. Baaghideh et al informed that the main factor limiting the distribution of oak and its deterioration is the temperature factor. Then, the wind-precipitation factor has enhanced the development of dense oak forests in antiquity by providing appropriate rainfall prerequisites (Baaghideh et al., 2013). The findings of are also consistent with the present study that increase in temperature and decrease in precipitation over time and consequently proliferation of oak declines (Vose et al., 2012).

Besides, the findings on the consequence of precipitation fluctuations on the appearance and development of Zagros forests in Lorestan and Ilam provinces confirm the present study results (Attarod et al., 2021). In addition, a group researchers also verified that the forest cover of Lorestan province is significantly prone to drought (Alirezaei et al., 2019). This point is consistent with the findings of the contemporary examination. As a result, for every 0.1 unit alter in the SPI index, the area of forest cover will vary 14880 ha in the same direction. In other words, if the standardized rainfall index tends to be moist, the forest cover will rise. The forest cover will be reduced to 14,880 hectares for every 0.1 units of inclination towards negative values if it shifts towards drought.

Climate change over time affects the biological and physiological conditions of plants, productivity, and forest growth. This change in evolution occurs by altering the temperature and the length of the growing season. In addition, it causes drought, fire, and the spread of pests and diseases. Numerous factors are contributing to climate change, including increased atmospheric carbon dioxide and greenhouse gases, land-use change, and fossil fuel consumption. With global warming, some tree species are unable to adapt to new conditions. However, some tree species have the ability to adjust to the latest settings. For example, species that are better able to survive in dry climates are more likely to adapt to new conditions, while trees that adapt to humid climates are more likely to destroy.

Trees are not able to absorb their required water, resulting in a physiological deficiency due to climate change (decrease in rainfall, increase in temperature, duration of drought, etc.) as a result of a physiological deficiency (Jahanbazi et al., 2020). If drought stresses occur continuously, the trees become severely physiologically weak, and the environment for secondary tension such as pest and disease outbreaks is prepared (Arend et al., 2011). As a result, the oak tree can no longer tolerate these unfavorable conditions and eventually declines (Batos et al., 2010). Under such conditions, the trees respond to the prolonged drought stress and eventually collapse. The tree's decline results from the conversion of starch stored in the roots into Carbohydrates to ensure the survival and metabolism of the trees. In severe and prolonged droughts, the starch reserves of the trees are suddenly depleted, and as a result, they are unable to maintain their current state and do not survive (Clatterbuck and Kauffman, 2006).

In physiological processes, water, in addition to providing the plant with the required moisture, recreates a crucial function in the transfer of minerals from the soil to the plant as well as the interaction of materials within trees. Whenever moisture decreases, the minerals transmitted from the soil to the plants are damaged, and the trees evolve suppressed (Arend et al., 2011). A gradual decrease in soil moisture disrupted the mineral interaction process in the plant. As a result, the growth condition of the trees is affected. In such cases, their tissues and organs eventually will be damaged (Clatterbuck and Kauffman, 2006). There are duplicated unfavorable effects of water shortage and soil moisture during the growing season, which result in fewer minerals being absorbed by the root system and reduce vegetative and reproductive growth (Sohar et al., 2014; Azim et al., 2022).

Climate change instances throughout the study area include rainfall reduction and diminished or even no snowfall in the peaks of mountains (e.g., Kachal Mountain with a height of 2355 m) that were previously covered by snow and ice in the cold and mild seasons. commonly, other examples include the increase in cold front instability, drying of permanent rivers (e.g. Chelleh and Sarnast), water level reduction of deep and semi-deep wells; prolongation of the growing season, and in some cases does not even fall on some species in the cold season, a premature or untimely flourish of some trees in mid-winter, the life cycle continuation of some insect's kinds and reptiles within the cold season. Mild temperatures in winter and more extended growing seasons may result in insect infestations and diseases that were not previously considered substantial concerns. While climate change involves the potential for insect outbreaks in numerous paths, a direct correlation between seasonal temperatures and population growth suggests that climate warming may be high and raise crises (Bale et al., 2002). The destructive impact of the pine beetle (P.mugo) in the northwestern United States is an example of an increase in winter temperature, with dense and old-growth forests predisposed to insect epidemics (Fettig et al., 2007).

Consistent with the present study results, Karmian and Mirzaei realized that the highest priority comprises drought and climate change (0.289) while the least importance includes quantitative and qualitative characteristics of the tree and its habitat characteristics (0.097) on the affecting factors on the Persian oak decline in Ilam province (Karmian and Mirzaei, 2016). Pourhashemi and Sadeghi also confirmed that climatic elements such as reduced rainfall, Elevation of air temperature, wind speed, sunlight, evaporation, transpiration, and even dust increased the likelihood of tree decline or aggravation (Pourhashemi and Sadeghi, 2020).

The sampling results in several sites showed that the frequency and stock of Persian oak species in the second period (2018) has decreased compared to the first period (1998); (e.g., reducing the mean cross-sectional area from 21.65 to 15.26 per hectare). So far, no study has been conducted on the monitoring of Persian oak stocks in the Zagros forests over time to compare results in different spans. However, there are some occasional reports from various years that generally indicate these forests' stock decadence over time. Consequently, the mean standing stock in the Shademan Charcoal-making project in West Azerbaijan in 1963 was 82.8 m3.ha. The second series of the Marivan coal-mining project in 1964 included 29.1 m3.ha. Furthermore, in the Heyanan charcoal harvest plan of Ilam in 1964, 41.75 m^3.ha were reported. Similarly, the mean standing stock has decreased from 43.8 m^3.ha in the Manj coal-mining project in Chaharmahal and Bakhtiari province in the 1960s to less than 13.5 m3.ha in the 2000s (Ebrahimi and Jazirei, 2013).

The quality, health, and infection conditions during sampling periods at the study sites were thoroughly opposite. The quality and health rate of Persian oak in the second sampling period show that the drought proportion is high in the initial category (<20) and in the intermediate classes (40-60 and 80-60), which ultimately results in the oak tree's mortality. The low ratio of trees in the > 80 classifications (upper category) because of their position to supply firewood, especially inaccessible areas, areas with recreational and ecotourism functions, seasonal fires, and so on. The qualitative status comparison in the second-period sampling (i.e., 2018) than the first period (i.e., 1998) exhibits that the oak decline and mortality rate were not negligible. The oak decline leads to a rising fuel in the forest, which also increases the number and severity of seasonal fires.

As noted, the reason for the reduction in the tree's frequency is the health and quality of the upper classes, including human factors and their consequences. Because despite the development of fossil fuel infrastructure, many villagers in the vicinity of forest areas persist in Persian oak wood for traditional and fuel purposes, which the critical source includes dried trees. The expanding leisure and camping approach in forest areas by local and non-native tourists is another influential factor. Because these activities are highly dependent on wood and firewood as a result dead trees are presumably the best source for this point. In case of fire, completely standing dead trees and fallen dead trees are more prone to fire than other trees. The presence of standing and fallen trees in the forest is an impressive factor in raising the frequency and intensity of fires in the Zagros forests, which have expanded sharply in recent years. Initially, the fuel in the forest floor includes grass cover, which eventually results in surface fire. However, after the oak decline occurs, the presence of dead trees, both standing and down, results in a transformation from a surface to a crown fire regime, which is much more destructive and severe.

5. Conclusion

It is complicated to deduce shifts in distribution, abundance, and the Persian oak decline in response to climate change. This point is a result of the deficiency of long and well-quality time series related to the oak distribution and somewhat due to extensive measures to change the land use in most landscapes. However, the present study results indicated that the role of climatic element instabilities on the Persian oak species decline along with other factors threatening the existence of the Zagros ecosystem is undeniable. Therefore, climate change, alteration in hydrological regime, and the appearance of severe drought tension are the characteristics that prevent trees from absorbing enough moisture and suffering from a physiological deficiency. As a result of physiological defects, the factors provided for an attack of various pests and disorders on the trees. Accordingly, the oak tree, which can no longer tolerate these threats, goes into mortality and decline.

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