DOI:10.5152/forestist.2024.23087
Forestist 2024: 74(3): 327-332

ISTANBUL UNIVERSITY
CERRAHPAŞA

Original Article

Drought-Induced Tree Decline Changed the Structure of Persian Oak Forests

Ahmad Hosseini
Department of Forests and Rangelands Research, Ilam Agricultural and Natural Resources Research and Education Center, AREEO, Ilam, Iran

ABSTRACT

To study the changes in structural characteristics of oak forests due to tree mortality, the Shalam forested area in the western Iran was selected. For this, 20 stands with different topographical conditions were selected to determine whether the stand or tree characteristics changed following tree mortality as well as were essential factors in the variation of tree mortality. In each stand, three plots of 1000 m^2 were established randomly and systematically, and variables of tree diameter (diameter at breast height), maximum and minimum crown diameter, origin and form of trees and shrubs of all species, crown dieback percent, and number of dead trees were measured and recorded. Results showed that the tree mortality rate in the study area averaged 35.33 trees/ha, and 97.65% of it was related to Persian oak. The amount of stand density, basal area, and canopy cover decreased by 15.7%, 14.23%, and 4.19%, respectively, due to tree mortality. The abundance of most species has decreased, and the rate of species frequency reduction was more remarkable in Persian oak and *Acer monspessulanum*. Of the trees, 20.37% were healthy, and 79.63% were affected by crown dieback. The highest density of tree mortality was in the diameter classes of 10–30 cm, and the highest rate of tree mortality was in the diameter classes of 5, 60, and 75 cm. Based on the dead tree density, the pattern of tree mortality was L-shaped, while based on the dead tree percentage, the pattern was U-shaped. Tree mortality correlated significantly with diameter at breast height. Multiple regression analysis also showed that tree mortality has a significant relationship with stand basal area, diameter at breast height, and stand canopy cover; so these variables played a significant role in variation of forest structure under effect of tree decline.

Keywords: Drought, Persian oak, stand structure, tree mortality

Introduction

Tree decline is a central problem that oak species in western Iran face (Aazami et al., 2018; Hamzehpour et al., 2011; Hoseinzadeh et al., 2018; Hosseini et al., 2017 Soleimani and Hosseini, 2019). Tree mortality, as a factor of changing the forest structure and composition, plays a vital role in the structural development of forest ecosystems (Franklin et al., 1987). This phenomenon has occurred in recent years in the oak forests of western Iran following severe droughts and has become a big problem (Aazami et al., 2017; Hoseinzadeh et al., 2018; Hosseini et al., 2017; Hosseini & Hosseini, 2022; Hosseini, 2023; Iranmanesh et al., 2014; Jahanbazi et al., 2020; Zarafshar et al., 2020). Drought is the initial and main factor that creates the underlying stress and physiological weakness in trees and shrubs and causes episodic tree declines (Kabrick et al., 2008; McDowell, 2008). However, following the drought, other factors, such as beetle outbreaks and charcoal disease, appear and impact on the mortality of oak trees. Drought usually affects at the regional level, but its effects as crown dieback and death of trees at the local level are controlled and changed by factors such as topography and stand structure (Stephenson, 1990).

Since the forest stands and trees are located on different topographic sites, they use various micro-sites and micro-climate conditions (Guarın & Taylor, 2005; Kabrick et al., 2008). According to this, they would have different structural characteristics such as growth rate, tree density, canopy density, and species composition. Trees with different sizes have different competition for light, water, and other resources within the stand (Linares et al., 2010; Olano et al., 2009). Thus, depending on the structural characteristics of a stand, forest communities may show different responses to climate change as different rates of death and outbreaks of pests and diseases (Linares et al., 2010). Hence, in the evaluation of drought stress effects as well as the dynamics of pests

Cite this article as:
Hosseini, A. (2024). Drought-induced tree decline changed the structure of Persian oak forests. *Forestist*, 74(3), 327-332.

Corresponding Author:
Ahmad Hosseini
e-mail:
Ahmad.phd@gmail.com

Received: November 26, 2023
Revision Requested: January 2, 2024
Last Revision Received: February 10, 2024
Accepted: March 22, 2024
Publication Date: July 8, 2024

and diseases, stand structure should be considered as a simple spatial context (Das et al., 2011; Linares et al., 2010).

Given that drought-induced tree decline has recently occurred in western forests of Iran, inadequate research has been done in the field of tree decline effect on the structure of forests or the relationship between the structural characteristics of the stands and tree mortality, such as the study of Hamzehpour et al. (2011) in oak forests of Fars province in southern Iran. They found that the most number of dieback trees (58.3%) were coppice, and located in diameter classes of 15 to 25 cm. Also, they showed that most of the affected trees had more than 75% crown dieback. Hosseini et al. (2017) stated that the highest mortality rates and crown dieback were found at higher elevations, and southern and western aspects. Their findings confirm increasing rates of tree mortality in stands with higher tree density and shallow soils.

However, drought-induced tree mortality has occurred in the world's forests, especially in oak forests, on which comprehensive studies have been carried out. For instance, Greenwood & Weisberg (2008) found that tree mortality is usually associated with stand density. Zhaofei et al. (2008) found that oak mortality positively correlated with crown width, and the mortality rate differed among oak species. Nepstad et al. (2007) stated that tree mortality rates in response to severe drought for large trees were 4.5 times, and for medium trees were double, while the smallest ones were less responsive.

The present study was conducted in oak forests that have suffered from tree decline. So we focus on the structural changes of these forests under the influence of tree mortality and try to determine the tree and stand variables distinguishing tree mortality in Persian oak stands. Thus, the specific objectives of this research were: 1) to determine the variation in Persian oak stand structure due to tree mortality, and 2) to identify the most critical structural variables in relation to tree decline.

Material and Methods

Site Description

This study was conducted in the Shalam forested area on the southwestern slope of Shalam mountain, located in the north of Ilam province in the west of Iran (Figure 1). The altitude range in this area was from 1500 to 2000 m above sea level. It has four main aspects and various slopes, from gentle to intense. The study site is located on some geological formations including; Pabdeh, Gurpi, and Quaternary. The climate in this area is characterized as semi-Mediterranean mountain, with warm, dry summers and cool, wet winters (Asakereh, 2007). Most precipitation falls from November to May, with 70% falling as rain (Asakereh, 2007). Soils in the study area. are shallow to deep with clay, clay loam, silty clay, and silty clay loam textures and good water holding and drainage capacity. The first crown diebacks on Persian oak trees were observed and reported in 2008. From 2007 to 2010, a sharp decrease in rainfall and an increase in temperature occurred in the region. So, according to the valid drought indices (SPI and Z), a severe drought occurred (Asakereh, 2007; Hosseini et al., 2017). The four-year average of rainfall and temperature in this region (2007 to 2010) was about 385.8 and 16.9, respectively, which has changed significantly compared to the long-term average until 2010 (579.9 mm and 16.8°C) (Hosseini et al., 2017).

Site Selection and Field Sampling

The area of the study site was determined on a topographic map with a scale of 1:50000. Then, layers of slope, aspect, and elevation of the study area were prepared using geographic information systems. For the aspect, four main geographical directions; for slope, three categories (0–30, 30–60, >60); and for elevation, two levels (1500–1700 and 1700–2000 m asl) were considered. The layers were overlapped, and the study area was stratified into 20 topographic homogeneity units. In each homogeneous unit, three circular plots 1000 m^2 were randomly systematically established, and variables such as diameter at breast height (DBH) of all trees (DBH >5 cm), maximum and minimum crown diameter, form of trees, species kind, and crown dieback percent were

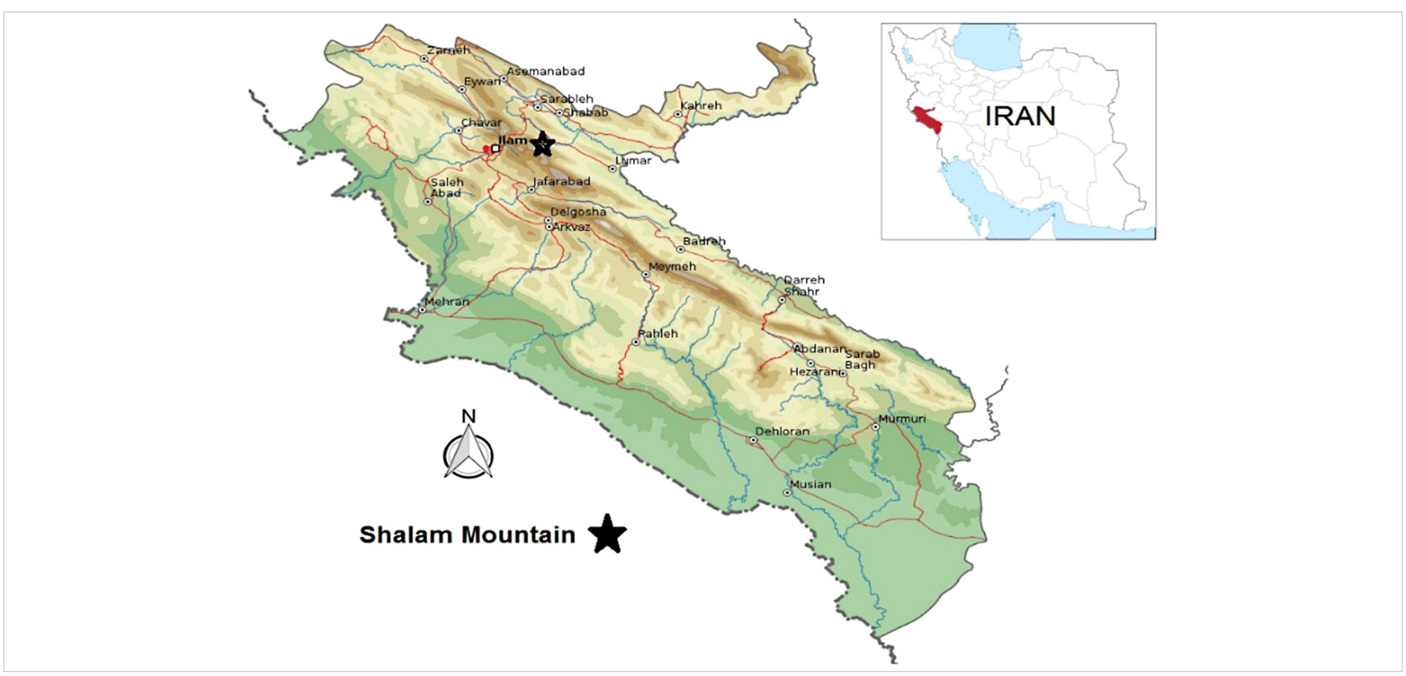

Figure 1.
The study site: Shalam mountain in the northern half of Ilam province in western Iran.

measured and recorded. Crown dieback evaluation and classification for each tree was done as; healthy = less than 5% crown dieback, weak = 5–33% crown dieback, moderate = 34–66% crown dieback, and severe = more than 66% crown dieback (Kabrick et al., 2008).

Statistical Analysis

After preliminary analysis of data, the statistical summary of variables such as tree and shrub density per hectare, basal area of tree and shrub species per hectare, canopy density of tree and shrub species, mean DBH of tree and shrub species, the density of dead trees per hectare, and crown dieback percent for each plot and homogeneous unit was computed. The equivalent diameter for the coppice trees was calculated from the following formula (Grier et al., 1992):

$$Equivalent\ diameter = \sqrt{\sum_{i=1}^{n} DBHi^2} \quad (1)$$

In the above equation: DBHi is the diameter at the breast height of shoot i in a coppice tree. To investigate the changes in stand structure variables as a result of tree mortality (the means comparison of stand structure variables between the pre-tree mortality situation or containing tree mortality data and the post-tree mortality situation or without tree mortality data), the paired *t*-test was used, and to study changes in density distribution in diameter classes, the Wilcoxon test used. The Kolmogorov–Smirnov test was used for the normality test of the data. Also, the Levene test was used to determine the homogeneity of variance. To analyze variance and multiple and paired comparisons of means, respectively, the one-way analysis of variance, Duncan, and *t*-test were used. Pearson correlation and multiple regressions were used in the Statistical Package for Social Sciences, version 16.0 software (SPSS Inc.; Chicago, IL, USA) in order to investigate the relationship between stand structural variables and tree mortality. To determine the most important structural variables related to tree mortality, regression models were examined and the best subset was selected, and the backward method also reached the same result.

Results

Tree Dieback and Mortality Status

The results showed that the amount and severity of tree dieback and mortality among the homogeneous units differed significantly (Table 1). The tree mortality rate in the study site averaged 35.33 trees per hectare, 97.65% of which were related to Persian oak. However, the average mortality of trees in the study site was 14.80%, which was slightly higher for Persian oak than the whole stand. Overall, 20.37% of the trees remained healthy, and 79.63% of them were affected by weak-to-severe crown dieback. Most of the trees were affected by weak crown dieback, and the lowest frequency of trees was in the crown dieback class of 66–100%, and the dead trees are part of this crown dieback class (Table 2). The mortality rate in coppice trees was higher than that of standard trees. However, the ratio of tree mortality (percentage of dead trees of each form to the total number of trees of the same form) in standard trees was higher than that in coppice trees (Table 2). Also, the diameter distribution of tree mortality indicated that the most amount of tree mortality is in the diameter classes of 10–30 cm (Figure 2), and the most percentage of tree mortality was in the diameter classes of 5, 60, and 75 cm (Figure 3).

Table 1.
Results of Analysis of Variance of Tree Mortality Among the Homogeneous Units in the Study Area

Tree Mortality Variables	*df*	Mean of Squares (MS)	*F*	Significance
Dead trees per ha	19	2587.368	6.336	.000
Dead trees (%)	19	288.891	4.123	.000

Table 2.
Tree Dieback and Mortality Variables at Stand Level in the Study Area

Tree Dieback Variables	Stand	Oak
Stand dead trees (n/ha)	35.33	34.50
Stand dead trees (%)	14.80	15.24
Coppice dead trees (%)	13.80	14.55
Standard dead trees (%)	17.99	20.97
Healthy trees (%)	20.37	19.93
Weak crown dieback trees (%)	41.88	41.91
Moderate crown dieback trees (%)	19.50	19.57
Severe crown dieback trees (%)	18.25	18.60

Changes in Species Composition

The results showed that the abundance of most species has decreased. The rate of this reduction for *Quercus brantii* Lindl., *Pistacia atlantica* Desf., *Acer monspessulanum*, *Crataegus puntica* C. Koch, *Amygdalus*

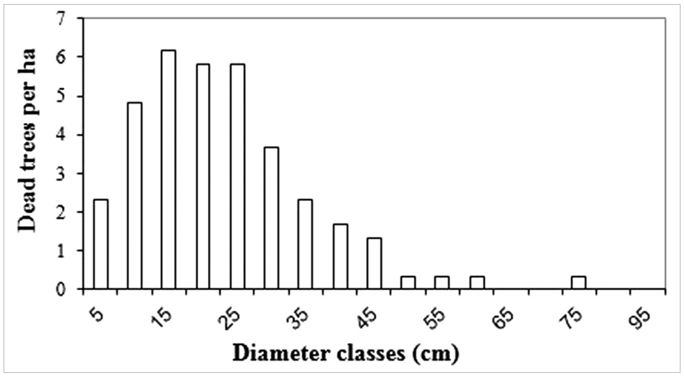

Figure 2.
Distribution of dead trees per hectare in the diameter classes of the study area.

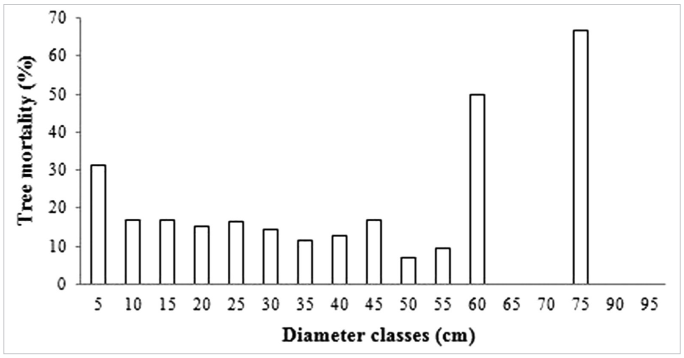

Figure 3.
Distribution of tree mortality percentage in diameter classes of the study area.

Table 3.
Composition Status of Tree and Shrubs Species in Two Stages Before and After Mortality

Species	Pre-Mortality Density (n/ha)	Pre-Mortality Percentage	Post-Mortality Density (n/ha)	Post-Mortality Percentage
Quercus persica	214.33	95.26	179.83	94.82
Pistacia atlantica	4	1.78	3.67	1.93
Acer monspessulanum	0.33	0.15	0.17	0.09
Cratagus puntica	5.33	2.37	5.17	2.72
Amigdalus orientalis	0.83	0.37	0.67	0.35
Cerasus microcarpa	0.17	0.07	0.17	0.09

orientalis L., and *Cerasus microcarpa* CA Mey. Boiss. were 16.10%, 8.25%, 48.48%, 3%, 19.28%, and 0%, respectively, but the share of each species in the total death of the stand was 97.71%, 0.93%, 0.45%, 0.45%, 0.45%, and 0%, respectively. The highest species frequency in the pre-mortality and post-mortality stages belonged to *Q. brantii* (Table 3).

Changes in Stand Density, Basal Area, and Canopy Density

The average stand density and basal area in the pre-mortality stage were 225 stems per hectare and 13.42 m^2 per hectare, respectively, which decreased by 15.7% and 14.23% following the occurrence of tree mortality, respectively (Table 4). Canopy cover in the pre-mortality stage was 32.52%, which reached 28.33% due to tree mortality (Table 4). T-test showed a significant difference between these two stages for the whole stand (Table 4).

Changes in the Diameter Distribution of Trees

The number of trees in the diameter classes in the pre-mortality stage (total surviving trees and standing dead trees) differed from the post-mortality stage (only surviving trees) and decreased (Figure 4). The highest number of trees in the pre-mortality stage was found in the 10–30 cm diameter classes, and the highest amount of tree mortality happened in these diameter classes (Figure 4). The results of the Wilcoxon test also showed a significant difference in the distribution of numbers in the diameter classes of trees before and after mortality (Table 5).

Tree and Stand Variables in Relation to Tree Mortality

Correlation analysis showed that the tree mortality has a negative and significant correlation with a DBH. However, it did not show a significant correlation with the rest of stand variables (Table 6). Multiple regression analysis showed that stand structure has a significant relationship with tree mortality. Based on the obtained model, stand basal area, diameter at breast height, and stand canopy cover showed the most relationship with the tree decline rate (Tables 7, 8 and equation 2).

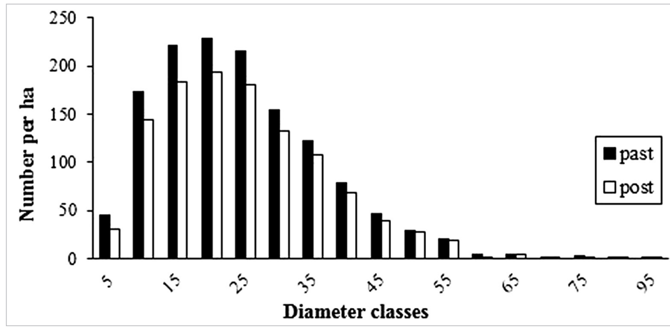

Figure 4.
Density distribution of stand trees in diameter classes in two situations before and after tree mortality.

Table 5.
Comparisons of Density Distribution in Diameter Classes in Two Situations Before and After Tree Mortality (Wilcoxon Test)

Variable	Z	Significance
Density	−3.192	.001

$$Deadtrees\% = 44.019 + 0.587g - 0.759dbh - 0.834crown \quad (2)$$

Discussion

Tree decline is an important phenomenon whose effects on forest structure have been proven in numerous studies (Flake & Weisberg, 2019; Greenwood & Weisberg, 2008; Hosseini et al., 2017; Valkonen et al., 2020). The results of the present study confirm this. The results showed that the composition of tree and shrub species, the distribution of trees in diameter classes, as well as the mean values of DBH, basal area, and canopy cover changed under the influence of tree decline. In the present study, Persian oak showed more sensitivity to drought, and many of its trees were affected by dieback. As the results showed, the average stand density was 225 trees per hectare, which decreased by 15.7%. Of this amount, 97.65% related to Persian oak species, attributed to the highest number of tree deaths. However, an examination of the mortality ratio of each species to its original frequency showed that the *Acer monspesulanum* was more damaged than the other species, and the Persian oak was in the second rank in this regard. Therefore, while the recent tree deaths have been affected by the species composition of the stands, it has also affected the species composition of the Shalam forests. These findings are consistent with the results of Elliott and Swank (1994) study that mortality rates in oak tree communities are different.

The mortality density of coppice trees was higher than that of standard trees, which may be due to the greater frequency of coppice trees than

Table 4.
Mean Stand Structural Variables in Two Situations Before and After Tree Mortality

Stand Variables		Pre-Mortality	Post-Mortality	*df*	*t*	Significance
Density (n/ha)	Whole stand	225	189.67	59	8.215	.000
Basal area (m^2/ha)	Whole stand	13.42	11.51	59	7.369	.000
DBH (cm)	Whole stand	24.58	24.86	59	7.226	.000
Canopy cover (%)	Whole stand	32.52	28.33	59	8.337	.000

Table 6.
Correlation Results of Stand Structural Variables with Tree Mortality in the Study Area

	Stand Density (n/ha)	DBH (cm)	SD	Basal Area (m²/ha)	Canopy Cover (%)	Oak Mixing (%)	Standard Trees Percentage
Tree mortality (%)	0.114	−0.368**	0.009	−0.041	−0.018	−0.075	0.001

Note: **Significance at the 99% probability level.

Table 7.
Analysis of Variance of Multiple Linear Regressions

Resource	*df*	Sum of Squares (SS)	MS	F	*p*	R^2_{adj}
Regression	3	2338.854	746.285	6.905	.000	23.1
Residual error	56	6052.823	108.086			
Total	59	8291.677				

Table 8.
Significance Test of Multiple Linear Regression Equation Coefficients

Predictor Variable	Coefficient	Coefficient Standard Deviation	*T*	*p*
Constant number	49.019	8.045	6.093	.000
Basal area (m²/ha)	0.587	0.448	2.561	.013
DBH (cm)	-0.759	0.241	−4.533	.000
Canopy cover (%)	-0.834	0.183	−3.189	.002

standard trees in the region. This result is consistent with the results of Hamzehpour et al. (2011). More death in coppice trees may be due to several shoots on one stump that naturally compete with each other for water and nutrients. In unfavorable conditions, such as the drought in the study area, the competition between the shoots in each coppice tree increases and harms their health. These findings are consistent with the results of Ruiz-Benito et al. (2013) on the greater concentration of tree mortality on the lower diameter trees due to coppice trees in the stand and the competitive pressure between them. In addition, the stumps that produced the coppice trees may be ancient, which is effective in their susceptibility to tree decline. However, the mortality percentage was higher in standard trees. Standard trees usually have a wider crown and more height than coppice trees, which play a negative role in stressful conditions and increase the tree's susceptibility to physiological weakness and death.

The DBH distribution pattern of tree mortality in the study area showed that the reduction amount in diameter classes of 10–25 cm was more than the other diameter classes (mortality pattern L-shaped). The reduction percentage was higher in the lowest diameter classes (2.5 to 7.5 cm) and the highest diameter classes (60 and 75 cm) (mortality pattern U-shaped). In other words, the pattern of diameter reduction in the study area forests was L- and U-shaped. The U-shaped mortality pattern has been widely observed in temperate and tropical forests (Ruiz-Benito et al., 2013; Toledo et al., 2011). The L-shaped mortality pattern has also been reported in Mediterranean forests (Ruiz-Benito et al., 2013). In both mortality patterns, the cause of low-diameter tree mortality, competition between trees for limited resources, and competitive pressure on them has been reported (Coomes et al., 2003; Ruiz-Benito et al., 2013). Therefore, low-diameter Persian oak trees that do not have more developed and stronger roots than the surrounding trees, lose root competitions for moisture, and sooner suffer from drought stress, so thereupon, disappear faster. The lower diameter classes are mostly related to coppice trees with a low mean diameter despite the number of shoots on a stump, and the results have already shown that the number of tree deaths in the coppice form was more than the standard form. Another part of the lower diameter classes is related to standard young trees. Low-diameter trees are less competitive than thicker trees and are more sensitive to drought stress under drought conditions, and sooner they are affected by drought and become weak (Coomes et al., 2003; Kabrick et al., 2004). Also, small-diameter trees, due to their low height, are placed in the shade of taller trees and under the pressure of their crown competition, which weakens sooner under drought stress (Kabrick et al., 2004). The cause of tree mortality in the highest diameter classes has been mentioned as old age (Ruiz-Benito et al., 2013). Trees with diameters of 60 cm and 75 cm were the oldest trees in the study area, and due to exposure to adverse environmental conditions over time, they are less resistant to drought stress than middle-aged trees, so they disappear earlier under drought stress (Coomes et al., 2003). Therefore, the diameter distribution of mortality can be considered as a pattern of tree mortality and be used as a guide in the management and applied silviculture of the studied oak forests.

The basal area of Shalam forests due to tree decline decreased by 14.23%, of which 95.29% belonged to Persian oak. Basal area is one of the indicators of forest density. In stands with the higher basal area, their biomass increases, and thereupon their water and nutrient requirements increase. In unfavorable environmental conditions, such as the occurred drought in the study area, the tree's competition for uptake soil moisture increases, and the trees, which are more sensitive to drought stress, become physiologically weak and gradually suffer from crown dieback and die. Studies have shown that the intensity of tree mortality increases with increasing stand density (Fierke et al., 2007; Greenwood & Weisberg, 2008; Voelker et al., 2008; Ruiz-Benito et al., 2013). For instance, Ruiz-Benito et al. (2013) found that high mortality in denser stands was due to water scarcity due to intense competition between trees. In this regard, Voelker et al. (2008) stated that more density in high-mortality habitats indicates that stand density is a predisposing factor for oak decline.

Canopy cover in the study area before death was 32.52%, reaching 28.33%. In this situation, the acute condition of the forest can be understood. The most important task of these forests is the protection of the region's water and soil, and this critical role is played by the forest canopy. The canopy plays a crucial role in creating a microclimate and maintaining favorable conditions in the forest. Given the widespread destruction caused by tree death and the severe reduction of the canopy cover, the forest canopy has been severely damaged, which has caused a severe disturbance in the ecosystem function. Indeed, this causes more light to penetrate the forest floor and the soil to lose its moisture faster and earlier. This action is more intense in drought conditions, putting additional pressure on the trees and their dying.

Conclusion and Recommendations

In this study, we proved that the structure of Persian oak forest stands had significant changes under the influence of the tree decline phenomenon, and the changes were mostly due to the many deaths that occurred in the Persian oak species. Persian oak was the dominant species in the forests of the region, and due to its abundance of more than 95% in all the studied stands, its changes have a great impact on the changes in the stand structure and tree and stand variables. However, these findings were obtained in a limited area of oak forests. According to this, we suggest a need for a research similar to the present study, but broader research in the western forests of Iran is necessary because it provides a complete understanding of the changed status of forests in different places as well as determining the pattern of tree mortality in different diameter classes, which can help provide management solutions.

Peer-Review: Externally peer-reviewed.

Declaration of Interests: The author has no conflict of interest to declare.

Funding: The author declared that this study has received no financial support.

References

- Aazami, A., hosseini, A., & hoseinzadeh, J. (2018). The effect of depth and aspect on soil moisture in dieback affected oak forests (case study: Meleh siah Forest, Ilam Province). *Ecology of Iranian Forests*, *6*(11), 41–50. [CrossRef]
- Asakereh, H. (2007). Temporal and spatial variations of precipitation in Iran during the last decades. *Iran Journal Development Geography*, *10*, 145–164.
- Coomes, D. A., Duncan, R. P., Allen, R. B., & Truscott, J. (2003). Disturbances prevent stem size-density distributions in natural forests from following scaling relationships. *Ecology Letters*, *6*(11), 980–989. [CrossRef]
- Das, A., Battles, J., Stephenson, N. L., & van Mantgem, P. J. (2011). The contribution of competition to tree mortality in old-growth coniferous forests. *Forest Ecology and Management*, *261*(7), 1203–1213. [CrossRef]
- Elliott, K. J., & Swank, W. T. (1994). Impacts of drought on tree mortality and growth in a mixed hardwood forest. *Journal of Vegetation Science*, *5*(2), 229–236. [CrossRef]
- Fierke, M. K., M.B., Kelley, M. B., & Stephen, F. M. (2007). Site and stand variables influencing red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae), population densities andtree mortality. *Forest Ecology and Management*, *247*(1–3), 227–236. [CrossRef]
- Flake, S. W., & Weisberg, P. J. (2019). Fine-scale stand structure mediates drought-induced tree mortality in pinyon-juniper woodlands. *Ecological Applications*, *29*(2), e01831. [CrossRef]
- Franklin, J. F., Shugart, H. H., & Harmon, M. E. (1987). Tree death as an ecological process. *BioScience*, *27*, 259–288.
- Greenwood, D. L., & Weisberg, P. J. (2008). Density-dependent tree mortality in pinyon-juniper woodlands. *Forest Ecology and Management*, *255*(7), 2129–2137. [CrossRef]
- Grier, C. C., Elliott, K. J., & McCullough, D. G. (1992). Biomass distribution and productivity of *Pinus edulis-Juniperus monosperma* woodlands of north-central Arizona. *Forest Ecology and Management*, *50*(3–4), 331–350. [CrossRef]
- Guarın, A., & Taylor, A. H. (2005). Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. *Forest Ecology and Management*, *218*(1–3), 229–244. [CrossRef]
- Hamzehpour, M., Kia-daliri, H., & Bordbar, K. (2011). Preliminary study of manna oak (*Quercus brantii* Lindl.) tree decline in Dashte-Barm of Kazeroon, Fars Province. *Iranian Journal of Forest and Poplar Research*, *19*(2), 352–363.
- Hoseinzadeh, J., Tongo, A., Najafifar, A., & Hosseini, A. (2018). Relationship between soil moisture changes and climatic indices in the MeleSiah forest site of Ilam Province. *Journal of Water and Soil*, *32*(4), 821–830.
- Hosseini, A. (2023). Comparison of Variability in Leaves and Roots Nutrient Contents of Persian Oak (Quercus brantii Lindl.) in Drought Affected Declining Forests. *BioResources*, *18*(2), 3885–3894. [CrossRef]
- Hosseini, A., & Hosseini, S. M. (2022). Contrasting foliar and soil nutrients responses to drought induced crown dieback in a Quercus brantii forest. *Dendrobiology*, *87*, 101–112. [CrossRef]
- Hosseini, A., Hosseini, S. M., & Linares, J. C. (2017). Site factors and stand conditions associated with Persian oak decline in Zagros mountain forests. *Forest Systems*, *26*(3), e014. [CrossRef]
- Iranmanesh, Y., Talebi, H., Sohrabi, H., Jalali, S. G.,. & Hosseini, S. M. (2014). Biomass and carbon Stocks of Brant's oak (Quercus brantii Lindl.) in two vegetation forms in Lordegan, Chaharmahal & Bakhtiari Forests. *Iranian Journal of Forest and Poplar Research*, *22*(4), 749–762.
- Jahanbazi, H., Iranmanesh, Y., Talebi, M., Shirmardi, H. A., Mehnatkesh, A. M., Pourhashemi, M., & Habibi, M. (2020). Effect of physiographic factors on absorption of essential nutritional elements of the leaf in Brant's oak (*Quercus brantii* Lindl.) affected by decline (case study: Helen forest, Chahamahal & Bakhtiari province). *Journal of Plant Research*, *33*(3), 544–553.
- Kabrick, J. M., Dey, D. C., Jensen, R. G., & Wallendorf, M. (2008). The role of environmental factors in oak decline and mortality in the Ozark Highlands. *Forest Ecology and Management*, *255*(5–6), 1409–1417. [CrossRef]
- Kabrick, J. M., Shifley, S. R., Jensen, R. G., Fan, Z., & Larsen, D. R. (2004). Factors associated with oak mortality in Missouri Ozark forests. Proceedings of the 14th central hardwoods forest conference, GTR-NE-316 (pp. 27–35). Wooster, Ohio, USA.
- Linares, J. C., Camarero, J. J., Bowker, M. A., Ochoa, V., & Carreira, J. A. (2010). Stand-structural effects on Heterobasidion abietinum-related mortality following drought events in *Abies pinsapo*. *Oecologia*, *164*(4), 1107–1119. [CrossRef]
- McDowell, N., Pockman, W. T., Allen, C. D., Breshears, D. D., Cobb, N., Kolb, T., Plaut, J., Sperry, J., West, A., Williams, D. G., & Yepez, E. A. (2008). Mechanisms of plant survival and mortality during drought: Why do some plants survive while others succumb to drought? *New Phytologist*, *178*(4), 719–739. [CrossRef]
- Nepstad, D. C., Tohver, I. M., Ray, D., Moutinho, P., & Cardinot, G. (2007). Mortality of large trees and lianas following experimental drought in an Amazon forest. *Ecology*, *88*(9), 2259–2269. [CrossRef]
- Olano, J. M., Laskurain, N. A., Escudero, A., & De La Cruz, M. (2009). Why and where do adult trees die in a young secondary temperate forest? The role of neighbourhood. *Annals of Forest Science*, *66*(1), 105–112. [CrossRef]
- Ruiz-Benito, P., Lines, E. R., Gómez-Aparicio, L., Zavala, M. A., & Coomes, D. A. (2013). Patterns and drivers of tree mortality in Iberian forests: Climatic effects are modified by competition. *PLOS ONE*, *8*(2), e56843. [CrossRef]
- Soleimani, R., & Hosseini, A. (2019). The impact of Persian oak (Quercus brantii Lindl.) on soil characteristics in a declining forest. *Journal of Forestry Research*, *31*(2), 1–8.
- Stephenson, N. L. (1990). Climatic control of vegetation distribution: The role of water balance. *American Naturalist*, *135*(5), 649–670. [CrossRef]
- Toledo, J. J., de Toledo, J. J., Magnusson, W. E., Castilho, C. V., & Nascimento, H. E. M. (2011) How much variation in tree mortality is predicted by soil and topography in Central Amazonia? *Forest Ecology and Management*, *262*(3), 331–338. [CrossRef]
- Valkonen, S., Aulus Giacosa, L. A., & Heikkinen, J. (2020). Tree mortality in the dynamics and management of uneven-aged Norway spruce stands in southern Finland. *European Journal of Forest Research*, *139*(6), 989–998. [CrossRef]
- Voelker, S. L., Muzika, R. M., & Guyette, R. P. (2008). Individual tree and stand level influences on the growth, vigor, and decline of red oaks in the Ozarks. *Forest Science*, *54*(1), 8–20. [CrossRef]
- Zhaofei, F., Kabrick, J. M., Spetich, M. A., Shifley, S. R., & Jensen, R. G. (2008). Oak mortality associated with crown dieback and oak borer attack in the Ozark Highlands. *Forest Ecology and Management*, *255*(7), 2297–2305. [CrossRef]
- Zarafshar, M., Negahdarsaber, M., Jahanbazi Gojani, H., Pourhashemi, M., Bordbar, S. K., Matinizedeh, M., & Abbasi, A. (2020). Dieback in pure stands of Brant's oak (*Quercus brantii* Lindl.) in southern Zagros forests, Kohmareh Sorkhi region of Fars Province. *Iranian Journal of Forest*, *12*(2), 291–303.