

Detection of high potential areas of persian oak forests decline in Zagros, Iran, using topsis method

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SILVICULTURE

ABSTRACT

Background: During the past decade, the phenomenon of Oak decline has affected valuable Zagros Oak Forests in western Iran. *Quercus brantii* as the most important tree species of these forests has been damaged more than any other species. Many factors are involved in this phenomenon. The purpose of this study was to identify areas with high potential for decline and determine the most important factors affecting it. In this study, using multi-criteria evaluation methods based on the Geographic Information System (GIS) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method and fuzzy logic, the map of decline potential of two selected stands (Dalab and Cheghasabz) in Ilam Province was prepared to reveal the high-risk areas of decline. The analytical hierarchical process was used to determine the weight of the factors.

Results: The results showed that both selected stands had decline potential. However, the Dalab stand at 25% and the Cheghasabz, at approximately 60% of the stand has an extreme potential for decline. Rainfall factors, pests, and diseases also have the greatest effect on Oak forest decline.

Conclusion: Due to socio-economic problems such as land use change, fire, tourism, grazing, and pruning, the Cheghasabz is more prone to decline than the Dalab, which was a forest reserve. The multi-criteria evaluation model used in the study can be a guide in identifying high-risk areas in other parts of the Zagros forests. The large area of critical areas in these two regions reveals the need for planning to implement support operations to reconstruct damaged ecosystems.

Keywords: *Quercus brantii*, Topsis, AHP, GIS-guided management, Conservation

HIGHLIGHTS

Making a map of the potential decline of two Oak forests (Dalab and Cheghasabz stands) in western Iran, with TOPSIS and fuzzy logic in GIS and determining the weight of Oak forest decline factors by AHP (analytic hierarchy process) method.

Rainfall factors, pests, charcoal disease, and land use change have the greatest impact on Oak forest decline. There was higher decline potential in Cheghasabz than Dalab due to more socio-economic problems. Areas with high decline potential were determined for management and conservation programs.

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INTRODUCTION

In recent years, disturbing reports have been provided of Oak decline in Zagros forests, suggesting that Oak forests in western provinces of Iran have been affected by this phenomenon (Amir Ahmadi *et al.*, 2015; Zandebasiri and Pourhashemi, 2016; Goodarzi *et al.*, 2016). Throughout the world, this disease has been found in many forests, in recent decades, and is known as "Oak silent death" (Pourhashemi *et al.*, 2017; Hamzehpour *et al.*, 2011). Its symptoms occur quickly and abruptly so that the Oak quickly dries up over a few months or the disease spreads rapidly throughout the healthy trees and can significantly damage its habitats (Zandebasiri *et al.*, 2017; Hosseini, 2014).

Iran is located in the arid and semi-arid climate belt of the world with only 7.4% area containing forests (Keenan *et al.*, 2015). The Zagros vegetation zone covers about 20 percent of Iranian soil in the west of the country (Karami *et al.*, 2017). Some references cite Zagros forests to be 5,500 years old (Marvie-Mohadjer, 2012; Ahmadi *et al.*, 2014). The area is referenced as a strategic ecosystem for a variety of socio-economic and biological reasons, and valuable environmental services (Mahdavi *et al.*, 2015; Ghadirian *et al.*, 2018).

In recent years, these forests have been heavily drained due to environmental stresses such as reduced rainfall, rising temperatures, drought, soil erosion, fire, dust, human impact, and pests that pose a serious threat to the future of the area (Hosseini *et al.*, 2012; Amir Ahmadi *et al.*, 2015). Deforestation of these forests has irreversible consequences, including reduction in forest canopy, soil erosion and biodiversity, disruption of ecological balance, villager migration, and desertification expansion (Kooch Soltani *et al.*, 2018; Ghadirian *et al.*, 2018). However, evaluation of the decline is still in its preliminary phase and no comprehensive study has been conducted on the exact causes. To date, various studies found to be effective have been conducted on this problem in different parts of Iran and around the world.

Many of these studies have divided the complex factors of Oak forest decline into several predisposing, inciting, and participant categories (Pourhashemi *et al.*, 2017; Zandebasiri *et al.*, 2017; Fan *et al.*, 2012; Wang *et al.*, 2012). In some studies, these factors are divided in two categories; namely, biological (pests and diseases) and non-biological (climatic elements, soil characteristics) factors (Linares *et al.*, 2011; Hosseini *et al.*, 2017; Kabrick *et al.*, 2008). In other words, several factors have contributed to the decline of Zagros Oak forests in Iran over the years, including climate factors (reduced rainfall, increased temperature, and duration of dry season) (Attarod *et al.*, 2017). However, some other reasons, such as human interference, have also provided grounds for the decline of these trees (Hosseinzadeh, and Pourhashemi, 2015). These factors weaken the ecosystem and Oak trees (Pourhashemi *et al.*, 2017). After the trees are weakened, other factors trigger and initiate this phenomenon. As a result, what causes the death of trees is the result of a combination of these factors. The combination, with different weight and share, determines the deteriorating conditions of Oak forest

stands in Iran (Attarod *et al.*, 2017; Hosseini, 2012; Karami *et al.*, 2017; Ghadirian *et al.*, 2018; Kooch Soltani *et al.*, 2018).

It is not possible to easily identify these factors and map them to find locations with high decline potential, due to the remote availability and extension of the area by surveying and field operations. This requires the use of up-to-date methods. Preparing a decline potential map can help identify potential areas of decline and prevent increase of this devastating trend (Karami *et al.*, 2017). Studies in this field have been conducted in Iran using logistic regression and neural network methods. The use of Multi Criteria Decision Making (MCDM) methods are considered in this study due to the high capability in providing a suitable solution for locating and identifying areas of potential decline (Mahdavi *et al.*, 2015; Ghadirian *et al.*, 2018). Today, with the development of new techniques and different models for zoning using RS and GIS methods, valuable studies have been conducted in different fields of natural resources. However, there has been neither empirical study on the definitive causes of decline by these methods nor preparation of potential decline maps. Studies have been undertaken by Kabrick *et al.* (2008) in the US, Gentilesca *et al.* (2017) in the Mediterranean, and Linares *et al.* (2011) in Morocco on the decline of Oak forests and their causes. However, few studies have investigated the causes of decline using multi-criteria evaluation methods. Among the few studies in this field is the study by Kooch Soltani *et al.* (2018) in Lorestan Province, using hierarchical analytical and fuzzy analysis to map the risk zones of Zagros Oak forests. For this purpose, they used slope, aspect, elevation, temperature and precipitation, dust, and soil factors as effective criteria for measuring decline. The weight of each criterion was calculated according to expert opinion, and the AHP method and fuzzy criteria maps were prepared using linear, increasing, and decreasing fuzzy membership functions (Gussian). In the present study, overlapping layers were used to map areas susceptible to Oak forest decline. The study results showed that southern and western areas were susceptible to severe deforestation with increasing altitude, reducing soil depth, increasing temperature and reduction of rainfall. Fuzzy operator 0.7 was the most accurate in measuring these factors.

In another study, Ahmadi *et al.* (2014) in Ilam Province, based on the AHP model, zoned climate, topographic variables, distance from roads and residential areas, and land cover to war zones were accessed on their susceptibility to decline. The results showed that climatic factors including mean annual rainfall, temperature, evaporation, and moisture had the highest score in the decline of the Persian Oak in the area; more than 36.7% of total area was at high-risk, and more than 51% of the area was at medium risk.

Unfortunately, reports have shown that large parts of Zagros Oak forests in Ilam Province in western Iran have been experiencing oak trees decline in recent years. Hence, in the present study, a map of Oak forest decline potential was developed using the geographic Information system (GIS) tool and fuzzy logic, and TOPSIS methods, which determined the most important criteria affecting this phenomenon by the analytical hierarchy process (AHP) method.

MATERIAL AND METHODS

Study area

The present study has been conducted in two forest stands with signs of Oak decline called Cheghasabz and Dalab in Ilam Province, western Iran (Fig. 1 and Tab. 1). These areas were selected after initial information, visitation, and consultation with experts from the Ilam Department of Natural Resources and Watershed Management. In general, the climate of the area is mild to moderately humid (Mediterranean) with mild, humid winters and summers, not too hot, but arid (General meteorological office of Ilam Province). According to recorded statistics of the Ilam Synoptic Station, absolute maximum temperature is 40.6 °C, absolute minimum temperature is -12.6 °C, and the mean annual rainfall is 350 mm. The soil of the area is classified as Lithosols and Calcaric Regosols soils (Mahdavi *et al.*, 2019). The forests in the area are mainly Persian Oak (*Quercus brantii*) in the form of seeding forest, and in some parts seeding and coppice forest. However, *Pistacia atlantica*, *Acer cinerascens*, *Cratagus azarolus* and *Cerasus microcarpa* species are also present with the Oaks. Although the phenomenon of decline is not limited to other species, this study focuses solely on Oak tree drying (Ilam Department of Natural Resources and Watershed Management Report, 2013).

Weighting the factors

The flowchart of the research method is described in Fig. 2. In this study, the primary target factors were

identified using library studies, field visits and opinions of forest experts. Given that factors affecting the decline of these Oak forests were not identified and no suitable criterion was available, the AHP method was used to investigate the causes affecting Oak decline in order to determine their effect on the decline. The stages of implementing the research method in this section are as follows: 1.1 Categorization of the above factors in the form of questionnaires and distribute between experts and locals obtaining mean scores given for each cause. At this stage, 14 final factors were selected (Tab. 2). 1.2 Weighing the factors using AHP method and AHP online calculator software. The basis of this method of decision-making is pairwise comparisons and the creation of hierarchical trees (Zandebasiri and Pourhashemi, 2016; Saaty, 1990). Applying this method requires the following steps (Muhammadi *et al.*, 2015): First: Define the problem at hand, introduce all the objectives of the problem, and set effective criteria. Second: Create factor structure by the Hierarchical Analytical Process and form a decision diagram. Third: Form pairwise comparison matrix. Fourth: Extract the coefficients of matrix significance and weight of the factors. The method of determining the weight of the factors is a pairwise comparison based on preference judgments values 1 to 9 and the Saaty Table (Saaty, 1990). Fifth: Pairwise comparisons matrix compatibility test. Saaty (1990) provided this stage known as the Consistency Ratio (CR). The acceptable CR ratio for matrix A should be less than 0.1. Sixth: Determine the rating or relative significance of decision

Tab. 1 Characteristics of studied forest stands (Cheghasabz and Dalab) in Ilam Province, western Iran.

Region	Distance to Ilam (km)	Slop	Elevation (m)	Location Coordinate	Area (ha)	Forest type
Cheghasabz	3.15	16.6	1560	33° 42' 03" N 46° 23' 00" E	2771	Pure Oak
Dalab	Dalab	Dalab	1834	33° 36' 33" N 46° 29' 49" E	2945	Pure Oak

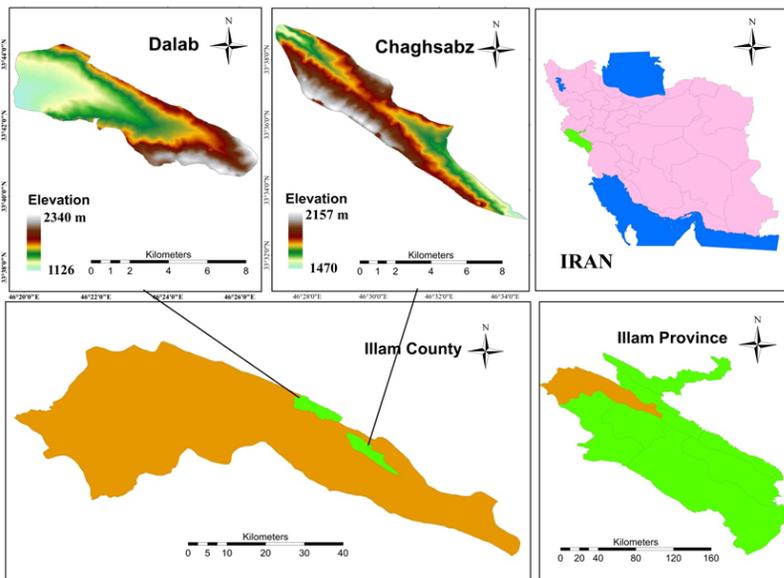


Fig. 1 Location of selected forest stands (Cheghasabz and Dalab) in Ilam Province, western Iran.

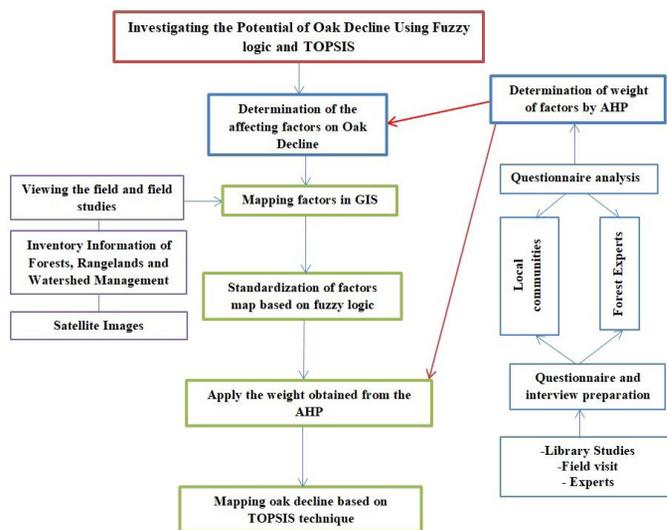


Fig. 2 Flowchart of Research Method.

Tab. 2 Weight of factors affecting Oak forest decline obtained from AHP method.

Factor	Weight	Factor	Weight
Annual Rainfall	0.149	Tourism	0.052
Pests	0.138	Fire	0.050
Charcoal disease	0.131	Slop	0.045
Land use change	0.115	Annual Temperature	0.030
Pruning	0.093	Elevation	0.027
Grazing	0.079	Canopy density	0.020
Aspect	0.061	Diameter at breast height	0.010

options ranking them in relation to the criteria and purpose based on scores obtained.

Prepare factors map

After determining the weight of the factors, the basic map was prepared. Prepare physiographic factor map (slope, elevation, and aspect) based on digital elevation model (DEM). Prepare climatic factor map (mean annual rainfall and temperature) using statistical information of synoptic stations and rain gauges of Iran Meteorological Organization. Prepare land use change map using field views and matching Google Earth image. Prepare pest and charcoal disease map using Ilam General Department of Natural Resources and Watershed Management data and field visits. The pests identified in the area belong to the families Cerambycidae and Buprestidae and charcoal disease (*Biscogniauxia mediterraneum*). Prepare a map of pruning, fire, livestock grazing, and tourism using field visits and interviews with experts and locals. Prepare silvicultural factor map (diameter at breast diameter and canopy density) based on Ilam General Department of Natural Resources and Watershed Management (2013).

Prepare standardized factor map

The fuzzy logic method (Zadeh, 1965) is generally used for the standardization of criteria (Kooh Soltani *et al.*, 2018). In this method, all values of the basic map layers are in

a range between 0 and 1 (Zadeh, 1965). The standardization process in the fuzzy method is implemented by formatting values into a membership set. Factor map fuzzification was performed using logic in GIS. Higher values of fuzzy membership function indicate higher forest decline potential.

Prepare the final map of the decline potential using TOPSIS method

The TOPSIS model was proposed by Hwang and Yoon (1981) (Hwang and Yoon, 1981). In this method, 'm' option is evaluated by 'n' index. It is assumed that the utility of each index is uniformly increasing or decreasing, which is defined as the ideal positive (A⁺) and ideal negative (A⁻). The technique is based on the notion that the chosen option should have the least distance to the ideal positive solution and the maximum distance to the ideal negative solution (Ertugrul and Karakasoglu, 2007).

Modeling steps by TOPSIS method

In this study, the TOPSIS model was implemented in eight steps, respectively, as follows (Mohammadi *et al.*, 2015): First: Form decision matrix using data collected and a data matrix based on 'n' index and 'm' option. Second: Non-scale decision matrix. Third: Determine weight of each index. Fourth: Convert decision matrix in step 2 into a non-scalar weighted matrix. Fifth: Find the ideal positive solution (A⁺) by determining maximum value and ideal negative solution (A⁻) by determining minimum value. Sixth: Calculate distance from ideal positive to ideal negative based on Euclidean method. Seventh: Calculate relative proximity of each option with the ideal solution. Eighth: Rank options based on their proximity to ideal solution. The final output is a spectral map in which the spectral values represent the rate of decline potential for the study area classified into four classes (low, moderate, high and extreme decline).

Modeling steps by TOPSIS method

To check the accuracy of the prepared decline potential map, field visits were made to areas with high and

extreme decline classes. To determine the degree of decline and drought, the health status of Oak in four categories was evaluated based on the percentage of canopy decline and observation of appearance at the location of random points in the field. Healthy trees without signs of the effects of drought, pests, and diseases on the trunk and canopy were examined. Those trees with weak decline (tops of branches or part of the crown are less than 25% dry), moderate decline (part of the crown is 25 to 50 percent dry), and severe decline (most of the main branches are dry and in total more than 50% of the crown is dry) were examined as well (Hosseinzadeh and Pourhashemi, 2015).

RESULTS

Factors affecting Oak forest decline

In this study, 14 final factors (climatic, physiographic, silviculture, and socioeconomic) were selected based on accumulated studies. Thereafter, relative weight and the coefficient of significance of each cause were determined based on the views of both experts and groups of local communities and based on the AHP method (Tab. 2). The results showed that the factors of rainfall, pests, charcoal disease, and land use change had the highest weight and the silvicultural factor had the least effect on Oak forest decline in the study areas, respectively.

Basic map and standardized map of factors affecting Oak forest decline

The information obtained from the factors listed in the form of a database with the same geo-referencing system (UTM, WGS 1984, Zone 38 N) was converted to a digital format in software GIS and the basic factor map was prepared. In this paper, only maps of the highest weighted factors are given (Fig. 3 and 4). In the next stage, all factors were standardized based on fuzzy logic and membership functions in which higher membership values indicate higher utility and lower membership values indicate lower utility for the given objective.

Prepare Oak forest decline prone area map by TOPSIS method

The map of Oak forest decline potential classes in the two studied stands was classified according to the mentioned method as low, moderate, high, and extreme classes (Fig. 5). The class area is shown in Fig. 6. The results showed that in the Dalab species 282.946 hectares had extreme decline potential, 455.51 hectares had high decline potential, 1635.57 hectares had moderate decline potential, and 571.30 hectares had low decline potential. In the Cheghasabz species, 619.9691 hectares had extreme decline potential, 1042.13 hectares had high decline potential, 701.87 hectares had moderate decline potential, and 406.84 hectares had low decline potential. In the Cheghasabz 59.98%, and in the Dalab 25.06% of the area had extreme decline potential. At a glance, the Cheghasabz species had the worse condition in terms of decline.

Validation of final maps

In order to verify the maps obtained from field visits, the area and ground control in the damaged decline classes with high and extreme decline was used. The coordinates of the study points and photos of the areas are presented in Tab. 3 and Fig. 7.

Tab. 3 Field validation matrix of Oak forest decline category.

Stand	Coordinates of points
Dalab	33° 43' 35" N 46° 21' 28" E
	33° 42' 56" N 46° 22' 23" E
	33° 42' 07" N 46° 22' 50" E
Cheghasabz	32° 38' 39" N 46° 27' 38" E
	33° 37' 29" N 46° 28' 46" E
	33° 36' 26" N 46° 33' 07" E
	33° 35' 03" N 46° 31' 32" E
	33° 34' 02" N 46° 32' 53" E

DISCUSSION

Analysis of factors in this study, using the AHP method, showed that the factors of rainfall, pests, charcoal disease and land use change had the highest weight. As shown, the most prominent role is played by socioeconomic reasons (38.9%), pests and diseases (26.9%), indicating the important role of these causes in the susceptibility of Oak forest decline. The study results by Ahmadi *et al.* (2014) in the same province based on this model and on climatic and topographic variables, distance from roads and residential areas, and vegetation, showed that climatic factors, including annual rainfall played the greatest role in the decline of Persian Oak forests. This shows annual rainfall to be the most influential factor, which was understood in the present study. Kooh Soltani *et al.* (2018) investigated the potential of Oak forest decline in Lorestan Province, Iran, using a fuzzy analytical hierarchical process. They incorporated a set of topographic, climatic, dust, and soil factors in the map of decline-prone areas. The results of this study also evaluated rainfall, temperature, and soil as the most important factors. A study by Ghadirian *et al.* (2018) showed that drought index was the most important and effective factor compared to socioeconomic factors on identifying forested areas with critical conditions.

The significance of this study is the consideration of more factors, especially pest, disease, and socioeconomic causes of the decline such as land use change, grazing, pruning, tourism, and fire-fallow cultivation taking into account local conditions. Other studies have used fewer and different numbers of factors (Ghadirian *et al.*, 2018; Ahmadi *et al.*, 2014; Kooh Soltani *et al.*, 2018). In general, lower altitudes, for more access, higher slopes, due to lower soil depth and erosion, and southern and western aspects, due to more drought and heat, and areas with lower rainfall and higher temperature, the presence of pests and diseases, and the presence of socioeconomic problems all have higher degrees of Oak forest decline.

Ilam Province is one of the provinces in western Iran that has been experiencing drought in recent years

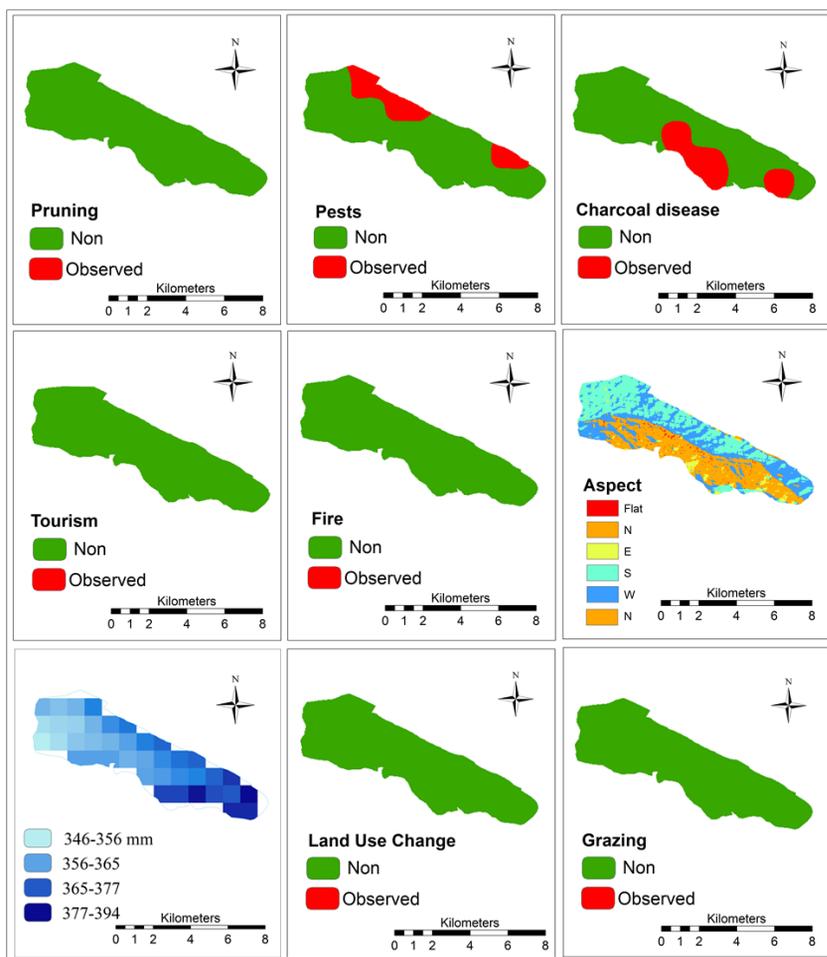


Fig. 3 Basic maps of factors in Dalab stands.

(Hosseini *et al.*, 2017). Drought stress can weaken the trees and their physiological properties and make them susceptible to pathogens such as fungi and pests (Attarod *et al.*, 2017; Pourhashemi *et al.*, 2017). The opportunistic nature of charcoal disease as well as wood and borer insects has infected more trees in the area. In Zagros forests, wood beetles have emerged after recent droughts, following drought, and physiological tree weakness, causing an acceleration in the mortality rate of drought-susceptible trees (Goodarzi *et al.*, 2016). These results are in accordance with the results of the Hosseini (2012) study on the conditions of Oak forest decline habitats with the presence of borer beetles. In this study, the presence of these factors in areas with higher potential for decline is evident in the final map. Studies by Jenkins and Pallardy (1995) in Ozark forests in Missouri, USA, have reported drought and the prevalence of *Armillaria* root rot as major causes of red oak trees death.

The life and livelihood of many people in this area of western Iran depend on these forests due to the large expanse of these forests. Therefore, some factors such as human interference have paved the way for the decline of these trees in various forms. Land use change, increasing levels of agricultural land, livestock entry and grazing, increase in the arrival of tourists, and as the course of decline has increased the lack of proper protection

has provided the grounds and conditions necessary to exacerbate this Oak forest decline (Hamzhepour *et al.*, 2011; Zandebasiri and Pourhashemi, 2016; Pourhashemi *et al.*, 2017). The present study showed that a number of different factors have played a role in the decline of Oak trees in the area, which is difficult to fully understand due to the long-term functioning of these factors in forest ecosystems and many other interferences. Therefore, the management of this environmental problem should take into account the effects of all primary and secondary causes, both directly and indirectly (Hamzhepour *et al.*, 2011; Zandebasiri and Pourhashemi, 2016; Pourhashemi *et al.*, 2017; Hosseini, 2014; Hosseini, 2012). Most pests and diseases penetrate trees through wounds in the trees. Cutting and pruning, fire, damage due to livestock grazing and agriculture on the forest floor, all cause damage to roots and soil compaction. These issues, while destroying forests and cause soil erosion, weaken the trees and reduce their resistance to pests and diseases (Hamzhepour *et al.*, 2011). Aber *et al.* (2002) also consider human activities as the intensifiers of the effects of natural and environmental events.

The map of Oak forest decline potential shows that the total forests of the two stands have decline potential. The area with higher degrees of decline is lower in the Dalab stand and higher in the Cheghasabz stand, so that in the

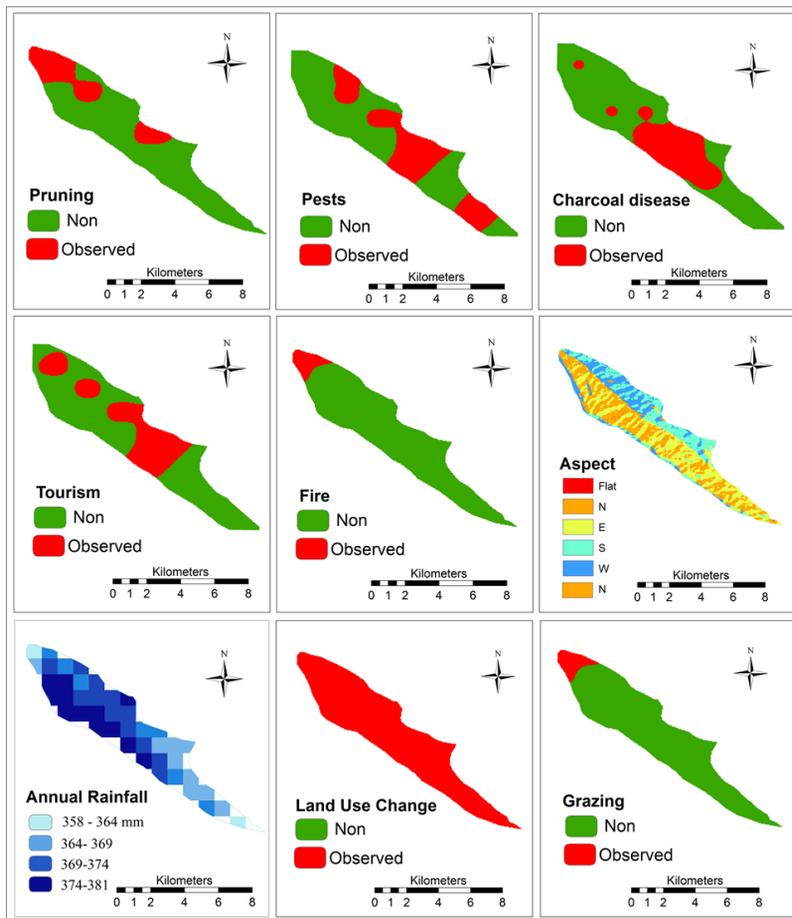


Fig. 4 Basic maps of factors in Cheghasabz stands.

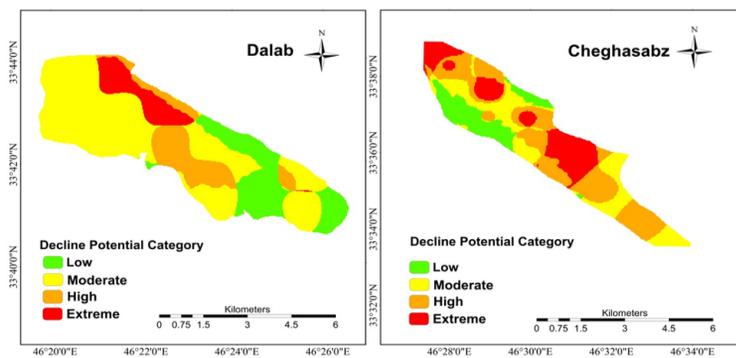


Fig. 5 Classification map of Oak decline potential in the study areas.

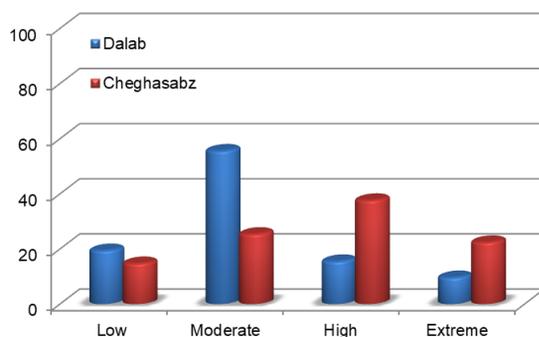


Fig. 6 Area of Oak decline potential in the study areas by TOPSIS method.



Fig. 7 Images of validation points in study areas (top: Dalab; bottom: Cheghasabz).

Dalab stand, 25% of the total stand has high and very high decline potential. This area is about 60% in the Cheghasabz stand. The Dalab stand has been a forest reserve for 10 years. Thus, we are less likely to see the effects of socioeconomic factors such as fire, tourism, livestock grazing, pruning, and land use change on the area. The Cheghasabz stand has greater economic and social problems and the presence of tourists, other villagers and their livestock, due to greater access and proximity to urban and rural population centers, and consequently fires, have been observed there.

Studies of Ahmadi *et al.* (2014) and Kooh Soltani *et al.* (2018) have also used multi-criteria evaluation methods, AHP and WLC, and the fuzzy analytical hierarchy process (AHP) methods, respectively. AHP is one of the most efficient decision-making methods that is based on pairwise comparisons, and allows managers to examine different scenarios. This process is a set of judgments and evaluations performed in a logical way (Saaty, 1990). The results obtained from previous studies show that the AHP method has a favorable application with respect to simplicity, flexibility, and the use of qualitative and quantitative criteria at the same time as well as the ability to examine the consistency of judgments related to location (Kooh Soltani *et al.*, 2018; Ahmadi *et al.*, 2014). The results of this study showed the applicability of methods such as AHP and TOPSIS due to the nature of their interactions and various criteria used in the study. This method has greater power and many advantages due to more simplicity and flexibility, than other methods, and has the ability to overlap with GIS (Muhammadi *et al.*, 2015). Therefore, the production of decline potential maps based on the model used can be suggested as a method to identify high-risk and crisis areas for other areas of these forests. The large area of critical areas in this study reveals the need for planning, as the first

step, to identify affected areas and implement conservation, support, and rehabilitation operations to rebuild damaged ecosystems and help to regenerate the said areas.

Below are practical suggestions: Need for planning in order to take more protective, stringent operations as the first solution. Provide decline potential maps, based on the model, as a method to identify high-risk and crisis areas for other areas of these forests. Perform various forestry operations such as large canopy pruning to reduce competition, reforestation, and management of stand composition towards species with more adaptation to drought, in addition to watershed management operations such as wastewater management and water storage. Development of identification programs for pests, diseases, and the perfect conservation of these areas in order to prevent or limit any kind of exploitation and mechanical control in the field. Help to reduce human pressures, control of grazing, and changes in land use, especially in critical areas, by developing multi-purpose forestry programs in local communities such as multi-use projects through workshops, and gradual replacement of fossil fuels with clean energy.

CONCLUSION

The decline of the Zagros Oak forest ecosystem is a multidimensional and complex phenomenon. The variety of factors affecting this phenomenon in different regions has made it very difficult to judge and plan for it. In this study, some factors affecting this phenomenon in western Iran in the Dalab and Cheghasabz stands in Ilam Province were studied by the AHP method. Overall results showed that rainfall, pests, diseases, and land use changes are the most

current reasons causing an effect on this phenomenon. fuzzy logic and the TOPSIS methods were used to construct the potential zoning map. The level of high-risk areas in Cheghasabz is higher due to the greater effects of socio-economic factors. Taking into consideration that all levels of two-stands forests have decline potential, the map of Oak forest decline potential, based on the model used in this study, can be used as a guide in identifying high-risk areas and applying protective conservation management in these areas. It is suggested that similar studies be undertaken in other parts of these forests based on the model used, in which other factors such as soil type and depth, amount of organic matter and soil moisture, and other ecological factors such as competition in Oak decline research be considered. The use of remote sensing technology and time-series satellite data to detect and evaluate forest changes can also play a key role in understanding the causes of Oak forest decline.

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AUTHORSHIP CONTRIBUTION

Project Idea: MJM and HK

Database: MJM

Processing: SBK and HB

Analysis: MJM, SBK and HB

Writing: MJM and HK

Review: HK, SBK and HB.

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