FORESTRY IDEAS, 2018, vol. 24, No 2 (56): 171–181

DECLINE MODELLING OF OAK TREES UNDER EFFECTS OF PHYSIOGRAPHIC FACTORS IN SEMI-ARID FORESTS OF IRAN

Mehrdad Mirzaei[1*], Amir Eslam Bonyad[1], Reza Akhavan[2], and Ramin Naghdi[1]

[1]Deparment of Forestry, Faculty of Natural Resources, University of Guilan, Sowmeh Sara, Iran.
[*]E-mail: mehrdadmirzaei28@gmail.com
[2]Forest Research Division, Research Institute of Forests and Rangelands, Tehran, Iran.

Received: 11 September 2018 Accepted: 05 December 2018

Abstract

Recent dust and droughts caused stress to physiological weakness of oak trees, so that insect outbreaks and pathogens lead to decline of oak trees in the Zagros forests. In addition to evaluate the effects of physiographic factors (elevation, slope and aspect) on the amount and distribution of decline, the objective of present study was to make a model of decline of *Quercus brantii* species in semi-arid forests of Iran. For this purpose, 509 hectares of Zagros forests, known as Dalab forests in Ilam province, were selected. Based on systematic-random sampling method, 100 circular plots (2000 m^2) were measured in grid inventory of 200×250 m dimensions. In each plot, physiography factors and percentage of decline were measured. ANOVA and Duncan tests were used to compare the decline of oak trees in different physiography factors. Then, an individual tree decline models were developed with a data set from a total of 1370 oak trees. To evaluate the effects of physiographic factors on the decline of oak trees, a logistic regression model was used. Omnibus test, log-likelihood, and pseudo r-square coefficients were used to evaluate the logistic regression model. The results showed that physiography factors had significant effects on the decline of oak trees. Also, the results showed that with increasing slope and elevation, the decline of oak trees was increased. Lowest and highest declines belonged to east and south aspects, respectively. Values of both statistics related to the pseudo determination coefficient are acceptable (0.395 and 0.584), and these values indicated that the three independent variables of this study had the power of a relatively high explanation of the variance and changes in the dependent variable of trees decline. The results of this study can be effective in the oak decline area conservation.

Key words: logistic regression, oak decline, physiography factors, Zagros forests.

Introduction

Zagros forests are located in the west of Iran and cover five million hectares. These forests are one of the most important and sensitive habitats for oak species that are classified as semi-arid and consist 40 % of Iran's forests. These forests provide various non-timber products, services and have multiple socio-economic and ecological functions. Due to uncontrolled cutting and overgrazing, Zagros forests have become degraded and have very low density. Natural regeneration is nearly non-existent, and severe soil erosion exposes the basic rock (Azizi et al. 2008, Marvi-Mohajer 2007). One of the main problems of Zagros forests is the decline of oak trees. Oak decline is characterized by crown thinning, foliar necrosis and progressive death of primary leaf-bearing branches and the emergence and subsequent decline of foliage. The condition of tree crowns is an important indicator of tree and forest health. A range of biotic and abiotic factors has been shown to contribute to the decline. However, no satisfactory investigation has been established to explain the distribution. The decline of Zagros forest ecosystem is a multidimensional phenomenon that various factors such as climate change, dust, lack of tree regeneration due to agriculture in the understorey, soil impaction due to livestock movement and oak pest and diseases are involved (Hamzehpour et al. 2011). Quantification and modelling of stand changes are important to the management of forest ecosystems. Therefore, forest modelling has been an intrinsic part of forest management planning and research for more than two centuries (Burnham 2002, Zheng and Zhou 2010, Lu et al. 2003). The majority of models operate at the stand-level and predict stand-level changes such as mortality and decline to provide information needed to estimate conservation costs, expected the yield and the financial result (Sheykholeslami et al. 2011). The key ingredient for obtaining a good decline model is a data set that is both large and representatives of the population under study. In many studies, linear and nonlinear regression was used for modelling of different tree variables in forests. Nonlinear regression including logistic, exponential and Chapman-Richard was used in different studies for modelling of the crown ratio of different species (Popoola and Adesoye 2012, Fu et al. 2015). Individual tree mortality models were developed for the six major forest species of Austria: European beech (*Fagus sylvatica* L.), European larch (*Larix decidua* Mill.), Norway spruce (*Picea abies* (L.) H. Karst.), Silver fir (*Abies alba* Mill.), Scots pine (*Pinus sylvestris* L.) and oak (*Quercus spp*.) by Monserud and Sterba (1999). Shifley et al. (2006) studied the oak mortality risk factors and mortality estimation in eastern North America and showed that mortality rates for trees in the red oak group were four to six times greater than mortality rates for associated trees in the white oak group. Also found that red oak group mortality was significantly related to tree crown class, tree diameter, and basal area of larger competitors. Kabrick et al. (2008) investigated the role of environmental factors in oak decline and mortality in the Ozark Highlands and showed that red oak mortality is more prevalent on droughty and nutrient-deficient sites because red oak group species are more abundant there. Fan et al. (2008) used logistic regression to study the oak mortality associated with crown dieback in the Ozark Highlands of Missouri and results of logistic regression showed that oak mortality was mainly related to crown width and dieback, and failed to detect any significant link with the number of oak borer emergence holes. The objectives of present study were to evaluate the effect of physiographic factors (elevation, slope and aspect) on the amount and distribution of oak decline trees and decline modelling of oak trees under effects of physiographic factors for *Quercus brantii* Lindl. species in semi-arid forests of Iran.

Material and Methods

Study area

The study area covered 509 ha in Dalab forests at 46°22'07″ E to 46°24'24″ E and 33°41'56″ N to 33°43'32″ N (Fig. 1). There was no permanent residential land in the study area, but dairy farmers and locals generally used the area for animal husbandry for about 2-4 months during spring and summer every year. The forests were under heavy pressure of livestock grazing, excessive cutting of trees and shrubs to supply fuel wood. The original vegetation of the study area was an uneven-aged mixed forest dominated by *Quercus brantii*, mixed *Quercus brantii – Pistacia atlantica – Acer cinerascens*, and mixed *Daphne mucronata – Amygdalus orientalis*. This area has a semi-arid climate based on the Emberger climate classification. Elevation ranges from 1450 to 1750 m a.s.l. and mean annual precipitation and temperature are 571.5 mm and 16.7 °C, respectively. In the main types division of lands, the study area was located in the mountain type and based on soil properties and their classification by

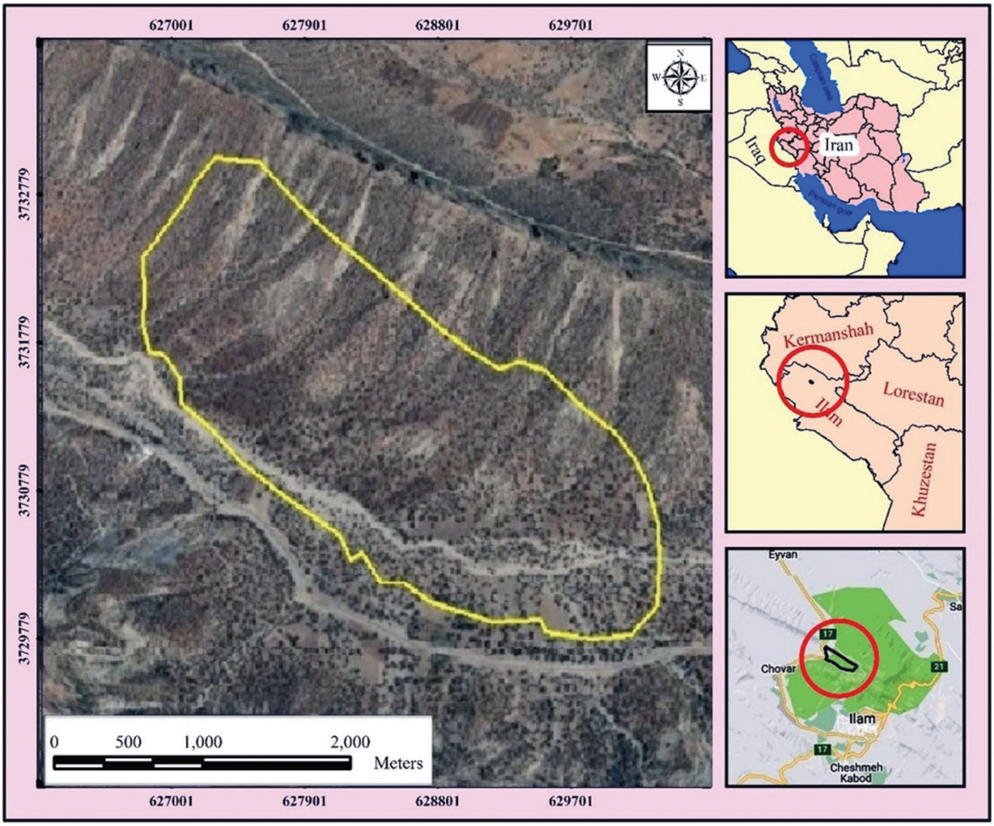

Fig. 1. Location of study area.

FAO, its soils are classified as lithosols (Rostami and Heidari 2009, Mirzaei and Bonyad 2016).

Methods

In order to collect data, 100 circular plots (2000 m^2) were measured in inventory grid of 200×250 m. In each plot, physiographic factors including elevation (1450–1550, 1550–1650 and >1650 m a.s.l.), slope (0–25, 25–50 and >50 %) and aspect (North, South, East and West) were measured and recorded. Also the existence or non-existence of decline in oak trees was recorded. In total, 1370 oak trees were measured.

Logistic regression was used in order to modelling individual tree decline for oak trees. Logistic regression is a statistical method for analysing a dataset in which there are one or more independent variables. The equation of logistic regression (Long 1997, Pampel 2000, Hosmer and Lemshow 2000) is the following (Equation 1):

$$P_{(decline)} = \frac{1}{1 - e^{-\alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n}} \qquad (1),$$

where: α is intercept, *e* is Naperian constant, β_1 to β_n is set of regression coefficients and X_1 to X_n is the independent variables.

ANOVA and Duncan tests were used to compare tree decline in different classes of physiographic factors. Logistic regression was used to investigate the relationship between oak decline and physiographic factors. Omnibus test, log-likelihood and pseudo *r*-square coefficients (including of Cox & Snell *R* square and Nagelkerke *R* square) were used for evaluation of the logistic regression model (Hosmer and Lemeshow 2000, Heydari et al. 2015). The values of the pseudo *r*-square coefficient stats are between 0 and 1, and the more these statistics are closer to 1, it shows that the role of independent variables is high in the explanation of the variance of dependent variable. Also, Hosmer and Lemeshow test was performed fitting of the predicted changes in the dependent variable (Hosmer and Lemeshow 2000, Heydari et al. 2015). Excel ver. 2013 (Microsoft Office) and IBM SPSS Statistics ver. 22 software were used for analysis of data.

Results

Descriptive statistics of the oak decline showed that 34.69 % of Dalab forests were decline in the study area. These statistics related to the oak decline are shown in Table 1.

The ANOVA test showed that there was a significant difference between oak decline in different slope classes (Table 2). According to Table 3, by increasing the percentage of slope factor, the oak decline was increased. Duncan test showed that the slope factor had significant effects on the decline of oak trees (Table 3).

The results showed that there was a significant difference between oak decline in the geographic aspects (tables 4 and 5). According to Table 5, the lowest and highest values of oak decline belonged to the east and south aspects, respectively. Also Duncan test showed that all geographic aspects had a significant difference in the oak decline values (Table 5).

Table 1. Descriptive statistics of oak trees decline in study area.

Variable	Mean, %	SD	CV, %	SE, %
Decline	34.69	9.22	26.57	5.31

Note: SD is standard deviation, CV is coefficient variation, SE is sampling error.

Table 2. ANOVA test of tree decline in different slope classes.

Indicator	Sum of squares	d.f.	Mean square	F	Sig.
Between Groups	7230.48	2	3615.24	187.01	0.000*
Within Groups	1875.13	97	19.33		
Total	9105.615	99			

Note: d.f. is number degrees of freedom, * is significant difference at the 0.05 level probability.

Table 3. Comparison mean of decline in different slope classes.

Slope classes, %	N	Subset alpha = 0.05		
		1	2	3
0–25	29	23.99		
25–50	42		34.48	
> 50	29			46.30

Table 4. ANOVA test of tree decline in different aspect.

Indicator	Sum of squares	d.f.	Mean square	F	Sig.
Between Groups	7538.981	3	2512.994	153.991	0.000*
Within Groups	1566.634	96	16.319		
Total	9105.615	99			

Note: * is significant difference at the 0.05 level probability.

Table 5. Comparison mean of decline in different aspect.

Aspect	N	Subset alpha = 0.05			
		1	2	3	4
North	11	26.54			
South	18		46.30		
West	42			34.48	
East	29				19.82

The results of ANOVA showed that elevation had significant effects on the oak decline (Table 6), so that by increasing of elevation, the oak decline was increased (Table 7).

Table 6. ANOVA test of decline in different elevation.

Indicator	Sum of squares	d.f.	Mean square	F	Sig.
Between Groups	1161.97	2	580.98	7.09	0.001*
Within Groups	7943.64	97	81.89		
Total	9105.615	99			

Note: * is significant difference at the 0.05 level probability.

Table 7. Comparison mean of decline in different elevation.

Elevation classes, m	N	Subset alpha = 0.05		
		1	2	3
1450–1550	41	31.07		
1550–1650	26		35.67	
1650–1750	33			38-96

According to the results of the Omnibus test, the fit of the model was acceptable and at a level of error less than 0.01 was significant. The results of Omnibus test are shown in Table 8.

Table 8. Omnibus test of model coefficients.

Indicator	Chi-square	d.f.	Sig.
Step	36.638	2	0.000
Block	688.716	7	0.000
Model	688.716	7	0.000

The values of both statistics related to the pseudo determination coefficient were acceptable (0.395 and 0.584), and these values indicated that the three independent variables of this study had the power of a relatively high explanation of the variance and changes in the dependent variable of oak decline. In fact, these three variables have been able to explain between 39.5 % and 58.4 % of the variations in the oak decline (Table 9). Also, the results of Hosmer and Lemeshow test showed that the research model was appropriate and has the necessary fit (Table 10).

Table 9. Results of model summary.

-2 Log likelihood	Cox & Snell *R* square	Nagelkerke *R* square
855.369	0.395	0.584

Table 10. Hosmer and Lemeshow test of model.

Chi-square	d.f.	Sig.
360.579	6	0.000

Results of variables entered on the model are shown in Table 11. The results of Wald statistic showed that all independent variables entered in the regression analysis were capable of predicting changes of dependent variable and their predictive ability at the probability level of 0.01 was significant. Also, the results of Exp (B) statistic showed that among the variables entered on the model, the slope variable has the highest ability to predict the impoverishment of trees, and the lowest ability was related to the elevation variable.

Table 11. Results of variables entered on model.

Variable	B	S.E.	Wald	Sig.	Exp (B)
E			110.073	0.000	
E_1	2.894	0.443	42.685	0.000	18.062
S			35.621	0.000	
S_1	-1.159	0.343	11.428	0.001	0.314
S_2	-1.830	0.311	34.675	0.000	0.160
A			77.246	0.000	
A_2	-1.577	0.426	13.702	0.000	0.207
A_3	1.874	0.423	19.659	0.000	6.512
Constant	-0.505	0.237	4.538	0.033	0.603

Note: E is elevation, E_1 is elevation in 1450–1550 m a.s.l., S is slope, S_1 and S_2 are slope in 0–25 and 25–50 % respectively, A is aspect, A_2 and A_3 are aspect in south and east respectively.

According to the results of Table 8, logistic regression model for oak decline trees is as follows (Equation 2):

$$P_{(\mathrm{decline})} = 1/(1 + \exp(-0.505 + 2.894\,E_1 - 1.159\,S_1 - 1.830\,S_2 - 1.577\,A_2 + 1.874\,A_3)) \qquad (2),$$

where: E_1 is elevation in 1450–1550 class, S_1 and S_2 are slope in 0–25 and 25–50 % respectively, A_2 and A_3 are aspect in south and east, respectively.

Discussion

The finding of present study showed that 34.69 per cent of Dalab forests were affected by the decline phenomenon (Table 1), which indicates that management operations should be taken as soon as possible to control and prevent the spread of oak decline in these forests. Evidences revealed that most of oak decline were located in areas that are classified as rain-fed agriculture and were affected by severe human intervention and exploitation in the region. In fact, the interaction of severe climate stresses, interferences and the presence of humans in the region has provided the necessary ground for increasing the decline of forest trees. The irregular distribution of rainfall and dry season length have more significant effect on the oak decline (Hamzehpour et al. 2011). In the present study, by increasing of slope and elevation factors, the rate of decline was increased (tables 3 and 7). Also, the lowest (23.99 %) and the highest (47.57 %) values of oak decline were in the slope classes 0–25 and >50 % (Table 3). Hosseini (2009) and Hosseinzadeh et al. (2015) reported that with increasing of elevation classes, rate of oak mortality was increased, which is in accordance with the results of the present study. Drohan et al. (2002) in their studies in Pennsylvania found that decline of maple trees occur at higher elevation. The effects of slope percentage on the oak decline were in accordance with the results of Lawrence et al. (2002), Kabrick et al. (2008), Kane and Kolb (2011) and Worrall et al. (2008) studies. By increasing the percentage of slope factor, the density of oak decline trees was increased and the density of healthy trees was decreased. In fact, by increasing the percentage of slope, moisture, soil depth and litter thickness decreases and these factors cause physiological weakness of the trees (Momeni Moghaddam et al. 2012). As the results show, the highest value of oak decline was in the southern and western aspects (tables 4 and 5). Sunlight intensity is higher in the western and southern aspects, providing more direct light and heat energy, which causes increasing the temperature, evapotranspiration and loses moisture. While the northern and eastern aspects receive low energy, so these aspects are cooler. Trees that are more restricted in the water condition (sun-directed) are more susceptible to drought (Suarez et al. 2004). Hosseinzadeh et al. (2015) showed that the rate of oak decline was higher in the southern than in the northern aspect, which is in accordance with the results of present study. Also, the results of this study are based on the results of Eckhardt and Menard (2008), which found physiographic factors of slope and aspect affecting pine (*Pinus taeda* L.) mortality in Central Alabama. Gerardin and Ducruc (1990) showed that the steep slopes in the sunshine directions in case of low rainfall are prone to soil drought and propagation drought stress for forest species. Extensive oak mortality and unprecedented abundance of oak borer populations are significant threats to forest health and economic value of timber. Regionally, there is a need to (1) identify trees and stands that are at high risk for oak decline, (2) forecast the mortality risk for individual trees within declining stands, and (3) select silvicultural treatments to mitigate decline.

The fitting and evaluation of models are an important part of modelling. According to the results of the Pseudo determination coefficient and Log-likelihood statistics (Table 9), it can be concluded that the logistic regression model of the study consists of three independent variables (elevation, slope and aspect) and dependent variable (decline) is a good model and the set of independent variables is capable of explaining the changes of decline. In other words, the set of independent variables have been able to explain 39.5 % to 58.4 % of the variations of decline variable (Table 9). Leites et al. (2009) showed that the logistic regression model has a high accuracy in estimation of the crown ratio for conifer forests in the United States that is in accordance with the results of this study. Mahdavi et al. (2015) using the logistic regression model and geographic information system showed that with increasing elevation in the western and southern aspects, forest cover density was increased and in areas with shallow soils and steep terrain the amount and distribution of dead standing oak trees were increased. Oak decline is widespread in the west of Iran that few studies have been done in this area, and consequently, specific causes for the phenomenon remain elusive. In general, physiographic factors are one of the most important sources of change in forest ecosystems (Bale et al. 1998). Although understanding their effects are complex due to the interaction of various factors, but an important part of it is due to light regulation and moisture regime (Kaufmann and Ryan 1986, Griffiths et al. 2009). Therefore, due to differences in the factors mentioned in different ecosystems, the comparison of the results of the present study with the results of other studies is not correct, but according to the results of this study and other researchers, it can be stated that the physiographic factors are very important in the estimation of quantitative characteristics of forest.

Conclusion

Oaks are major component of the Zagros forests but due to decline phenomenon, vast area of these forests has been lost. Slope, aspect and elevation of physiographic factors affected the decline of oak trees. By increasing slope and elevation, percentage of the oak decline was increased. Determining the effects of these factors helps to identify areas that are in this situation or are at risk of developing a phenomenon of decline. It should be stated that quantitative and qualitative characteristics of each forest are a function of physiographic factors, the microclimate of the region, management and operation of the forest, geographical location, environmental and soil factors, species types and other factors. Also, logistic regression model that was used through our analyses can be used to estimate decline from knowledge of slope, aspect and elevation, information that is routinely collected during forest inventories. These models can be used to guide marking prescriptions during thinning and harvesting operations.

Acknowledgments

This paper presents results from a research project entitled 'Estimation and mapping of decline forest stands in Ilam province using geostatistics and deterministic methods'. The research was sponsored by the Presidential Office, Department of Science and Technology, Iran National Science Foundation (95818244). The authors are grateful to the Iran National Science Foundation.

References

AZIZI Z., NAJAFI A., SOHRABI H. 2008. Forest canopy density estimating, using satellite images. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVIII. Part B8. Beijing 2008: 1127–1130.

BALE C.L., WILLIAMS J.B., CHARLEY J.L. 1998. The impact of aspect on forest structure and floristics in some Eastern Australian sites. Forest Ecology and Management 110: 363–377.

BURNHAM R.N. 2002. Dominance, diversity and distribution of lianas in Yasuni Ecuador: Who is on top? Journal of Tropical Ecology 18: 845–864.

DROHAN P.J., STOUT S.L., PETERSEN G.W. 2002. Sugar maple (*Acer saccharum* Marsh.) decline during 1979–1989 in northern Pennsylvania. Forest Ecology and Management 170: 1–17.

ECKHARDT L.G., MENARD R.D. 2008. Topographic features associated with *loblolly pine* decline in central Alabama. Forest Ecology and Management 255: 1735–1739.

FAN Z., 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: 2297–2305.

FU L., ZHANG H., LU J., ZANG H., LOU M., WANG G. 2015. Multilevel Nonlinear Mixed-Effect Crown Ratio Models for Individual Trees of Mongolian Oak (*Quercus mongolica*) in Northeast China. Plos One 10(8): e0133294.

GERARDIN V., DUCRUC J.P. 1990. An objective approach to evaluating natural drainage of forest mineral soils for non-specialists. Vegetatio 87: 127–133.

GRIFFITHS R.P., MADRITCH M.D., SWANSONA A.K. 2009. The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. Forest Ecology and Management 257: 1–7.

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.

HEYDARI M., POORBABAEI H., ESMAILZADEH O., SALEHI A., ESHAGHI RAD J. 2015. Indicator plant species in monitorin forest soil conditions using logistic regression model in Zagros oak (*Quercus brantii* var. *persica*) forest ecosystems, Ilam city. Journal of Plant Researches 27(5): 818–828.

Hosmer D.W., Lemeshow S. 2000. Applied Logistic Regression. Third Edition. New Jersey: John Wiley & Sons. 528 p.

Hosseini A. 2009. Investigation the affection rate of oak trees to mistletoe, *Loranthus europaeus*, in forests of Zagros area (A case study of Southern slope of Manesht Mountain in Ilam Province). Iranian Journal of Forest and Range Protection Research 7(1): 26–35.

Hosseinzadeh J., Aazami A., Mohammadpour M. 2015. Influence of topography on Brant`s oak decline in Meleh-Siah Forest, Ilam Province. Iranian Journal of Forest and Poplar Research 23(1): 190–197.

Kabrick M., Dey J., Daniel C., Randy G., Wallendrof J. 2008. The role of environmental factors in Oak decline and mortality in the Ozark Highlands. Forest Ecology and Management 255: 1409–1417.

Kane J.M., Kolb T.E. 2011. Site and species differences in tree mortality within mixed-conifer forests of northern Arizona. 96th Ecological Society of America Conference, Austin, TX. August 7–11, 2011.

Kaufmann R.M., Ryan G.M. 1986. Physiographic, stand, and environmental effects on individual tree growth and growth efficiency in subalpine forests. Tree Physiology 2: 47–59.

Lawrence R., Moltzan B., Moser K. 2002. Oak decline and the future of Missouri s Forests. Missori Conservationist 63: 11–18.

Leites L.P., Robinson A.P., Crookston N.L. 2009. Accuracy and equivalence testing of crown ratio models and assessment of their impact on diameter growth and basal area increment predictions of two variants of the forest vegetation simulator. Canadian Journal of Forest Research 39: 655–665.

Long J.S. 1997. Regression Models for categorical and limited dependent variables. Thousand Oaks, CA: Sage Publications. 328 p.

Lu Y.C., Lei X.D., Jian D.L. 2003. A new function for modeling diameter frequency distribution in the tropical rain forest of Xishuangbanna, Southwest of China. Forestry Studies in China 5(2): 1–6.

Mahdavi A., Mirzaei Zadeh V., Niknezhad M., Karami O. 2015. Assessment and prediction of oak trees decline using logistic regression model (Case study: Bivareh forest, Malekshahi-Ilam). Iranian Journal of Forest and Range Protection Research 13(1): 20–33.

Marvi-Mohajer M.R. 2007. Silviculture. University of Tehran. 387 p.

Mirzaei M., Bonyad A.E. 2016. Comparison of fixed area and distance sampling methods in open forests: case study of Zagros Forest, Iran. Journal of Forestry Research 27(5): 1121–1126.

Momeni Moghaddam T., Sagheb-Talebi K., Akbarinia M., Akhavan R., Hosseini S.M. 2012. Impact of some physiographic and edaphic factors on quantitative and qualitative characteristics of Juniper forest (Case study: Layen region – Khorasan). Iranian Journal of Forest 4(2): 143–156.

Monserud R.A., Sterba H. 1999. Modeling individual tree mortality for Austrian forest species. Forest Ecology and Management 113: 109–123.

Pampel F.C. 2000. Logistic regression: A primer. Sage University Papers Series on Quantitative Applications in the Social Sciences, 07-132. Thousand Oaks, CA: Sage Publications.

Popoola F.S., Adesoye P.O. 2012. Crown ratio models for *Tectonia grandis* (Linn. f) stands in Osho forest reserve, Oyo state, Niğeria. Journal of Forest Science 28(2): 63–67.

Rostami A., Heidari H. 2009. Typology of forest stands and evaluation of their overall status in natural forest of Dalab region, Ilam province. Journal of Agricultural Sciences and Natural Resources 15(6): 274–277.

Sheykholeslami A., Kia Pasha Kh., Kia Lashaki A. 2011. A study of tree distribution in diameter classes in natural forests of Iran (Case study: Liresara forest). Annals of Biological Research 2(5): 283–290.

Shifley S.R., Fan Z., Kabrick J.M., Jensen R.G. 2006. Oak mortality risk factors and mortality estimation. Forest Ecology and Management 229: 16–26.

Suarez M., Ghermandi L., Kitzberger T. 2004. Factors predisposing episodic drought-induced tree mortality in Nothofagus site, climatic sensitivity and growth trends. Journal of Ecology 92: 954–966.

Worrall J., Egeland L., Eager T., Roy A., Erik W., Johanson P., Wayne A., Shepperd D. 2008. Rapid mortality of populous tremuloides in southwestern Colorado, USA. Forest Ecology and Management 255: 686–696.

Zheng L., Zhou X. 2010. Diameter distribution of trees in natural stands managed on polycyclic cutting system. Forestry Studies in China 12(1): 21–25.