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# EFFECT OF FOREST HABITAT ON THE DISTRIBUTION OF LICHEN SPECIES IN ŞERIF YÜKSEL RESEARCH FOREST (BOLU, TURKEY)

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**Abstract**

The paper presents the results of a study evaluating impact of habitat factors on distribution of lichen species in a forest ecosystem, in Şerif Yüksel Research Forest (Bolu-Turkey), by applying "binary logistic regression" as the main analysis tool. The variables used for logistic regression were tree species, forest purity, altitude, slope, aspect, tree diameter and number of lichen species. Since it may only be possible to be installed within the model when the number of surveillance of the species is more than 20 in the study area. Distribution of 42 of the 82 epiphytic lichen species were modeled by logistic regression. It is concluded that among these variables, "number of lichen species" and "to be a mixed forest" were the most appropriate variables used in the models. In conclusion, binary logistic regression model can be successfully used in lichen species distribution in forest habitat.

**Key words:** Binary logistic models, Lichen distribution models, Present-absent data, Forest habitat.

## Introduction

Lichen are cosmopolitan in distribution, which are found from poles to the equator in different habitats (Galloway, 1996). They can survive on various substrata e.g. on tree barks, soil, rock surfaces and fractures or on buildings (on the walls) (Weber & Budel, 2001). Distribution of lichen species are affected by the substrate where they are found. Lichens living on the rocks are influenced by the characteristics of the rocks (Purvis *et al*., 1992; Sevgi & Makineci, 2005). Similar situation is also true of other substrates. Factors affecting the distribution of lichen species can be grouped as natural ones and anthropogenic ones. The natural factors include soil, climate, vegetation and land surface properties of the habitat. For instance according to vegetation, tree species with different diameters or bark properties can be diverse habitat for different lichen species. Habitat characteristics changed by anthropogenic activities also affect the distribution of lichen species. For example, anthropogenic pollutants can finally lead to the disappearance of some species (Gries, 1996; Kapusta *et al*., 2004). For applications made under the habitat management, the existence of lichens is directly affected (Abbey *et al*., 2000; Boch *et al*., 2013).

Generic diversity of the lichens is also affected by the characteristics of the stands (McCune *et al*., 2000). Different studies carried out in various habitats showed the relationships between stand age and lichens (Price & Hochachka, 2001; Kapusta *et al*., 2004). In these studies, it was determined that stand age affects the internal dynamics of the area. Similarly, age of the tree also affects bark characteristics. Therefore, stand age is an important variable that is used in lichen studies in forests. Most of the time, tree diameter is also used, which is easier to measure. (Stevenson & Enns, 1993; Hedenas & Ericson, 2000; Kantvillas & Jarman, 2004). However, the species mixture of the stands (Boch *et al.,* 2013; Price & Hochachka, 2001) and their topographic features also affect the presence, amount and diversity of the lichens (Price & Hochachka, 2001; Ihlen *et al*., 2001; Çobanoğlu & Sevgi, 2009).

Lichen communities are strongly patterned on macroclimatic gradients in forest temperature and moisture (Jovan, 2008). However, microclimatic properties in forests effect the distribution (absent/present) of lichen species. The availability of lichen species in the habitats is in line with the use of logistic regression models that can be used successfully in events with the binary results (Friedel *et al.*, 2006).

The presence of lichens in an environment or the temporal reduction in number is considered as an important indicator to decide that how to protect and manage the existing habitats. Such type of indicator lichen species are very helpful to know about the air quality of a place (Jovan, 2008; Jovan & McCune, 2005) and forest health (McCune, 2000).

In the present study, binary logistic regression modeling was applied to the epiphytic lichens in a specified forest area in Bolu (Turkey); distribution of lichen species was analyzed through the presence and absence of species by using the variables (features of forest habitat) such as tree species, forest purity, altitude, slope, aspect, tree diameter, and number of lichen species.

## Materials and Methods

**Research area:** Şerif Yüksel Research Forest is differentiated from Aladağ Forestry Management. It is located between 40° 35' 00" – 40° 39' 00" northern latitudes and 25° 33' 00" – 25° 38' 00" eastern longitudes. It has 1544 ha covering area with the highest point of 1640 m and the lowest point of 1330 m and is moderately rough (Tosun, 2003). The average annual mean temperature is 5.7°C (1975–1995) and the annual precipitation is about 882.6 mm according to Şerif Yüksel Research Forest Meteorological Station. The climate type is symbolized as $B_4C_2'rb_2'$ according to Thornthwait, that is humid, micro thermal, not or very few lack of water, partly under sea impact. The number of days with snow cover is 144 and with fog is 60 (Serin, 1998). The region is Mesozoic tarsier geologically (Irmak *et al*., 1962). The main rock is Andesite and its derivatives. Soil profile skeleton is medium and well-permeable. The pH values of soils are between 4.80 and 6.85 (Akgül & Aksoy, 1978; Kantarcı, 1979). Dominated tree species in the study area are *Pinus sylvestris* L. (Scotch pine) and *Abies bornmülleriana* Mattf. (Uludağ fir) (Bozakman, 1976). Şerif Yüksel Research Forest area is rich in lichen species (Çobanoğlu *et al.,* 2008, Sevgi *et al.,* 2010).

**Collecting samples:** Epiphytic lichen specimens were collected on a total of 219 tree substrata from 27 sampling sites in Şerif Yüksel Research Forest in Bolu from August 2004 to July 2005. The sampling area is composed of 10 mixed forest sites (FM1) and 17 pure forest sites including 175 fir tree (A) and 44 pine tree (P) (Table 1). Tree species on which lichens collected were *Abies bornmülleriana* Mattf. and *Pinus sylvestris* L.

Lichen material was picked on stems and branches up to 2 m height of the selected trees with various diameters. The lichen samples were collected together with bark substrates and put into paper bags in the field. They were then left to air drying and put into herbarium envelopes. The vouchers were stored in the herbarium of the Faculty of Science and Arts at Marmara University (MUFE), as collection numbers G.Ç. 1799 to 1908, and some duplicates in the herbarium of the Faculty of Forestry, İstanbul University (ISTO). The specimens were identified at species level by following the Flora books and keys (Clauzade & Roux, 1985; Purvis *et al.,* 1992; Wirth, 1995; Clerc, 2006; Groner, 2006). The nomenclature follows recent literature (e.g. Blanco *et al.,* 2004; Clerc, 2006; Groner, 2006; www.indexfungorum.org).

**Table 1. Characteristics of sampling sites*.**

| Site number | Eastern longitudes | Northern latitudes | Altitude (m) | Aspect | Slope (%) | Sampled tree |
|---|---|---|---|---|---|---|
| 1 | 25º 35' 54" | 40º 36' 47" | 1530 | NE | 8 | A(9), P(2) |
| 2 | 25º 35' 48" | 40º 36' 27" | 1560 | NW | 4 | A(7), P(3) |
| 3 | 25º 36' 06" | 40º 37' 00" | 1540 | NE-N | 6 | A (10) |
| 4 | 25º 35' 26" | 40º 35' 58" | 1540 | SW | 6 | A(3), P(7) |
| 5 | 25º 33' 57" | 40º 36' 24" | 1420 | SE | 3 | A(9), P(1) |
| 6 | 25º 35' 17" | 40º 36' 42" | 1540 | SW | 12 | A(10) |
| 7 | 25º 35' 45" | 40º 37' 24" | 1570 | W | 2 | A(10) |
| 8 | 25º 35' 38" | 40º 37' 20" | 1580 | SE | 6 | A(10) |
| 9 | 25º 36' 28" | 40º 37' 16" | 1560 | E | 13 | A(10) |
| 10 | 25º 36' 29" | 40º 37' 56" | 1610 | NW | 4 | A(10) |
| 11 | 25º 36' 17" | 40º 36' 41" | 1560 | SE | 15 | A(5), P(5) |
| 12 | 25º 37' 01" | 40º 36' 57" | 1540 | SE | 2 | A(7), P(3) |
| 13 | 25º 34' 23" | 40º 37' 41" | 1590 | SE | 14 | A(10) |
| 14 | 25º 35' 16" | 40º 36' 24" | 1520 | S | 16 | A(5) |
| 15 | 25º 34' 44" | 40º 36' 14" | 1480 | S | 18 | A(5), P(5) |
| 16 | 25º 34' 30" | 40º 35' 20" | 1440 | SW | 24 | A(5) |
| 17 | 25º 34' 02" | 40º 35' 48" | 1370 | W | 27 | A(5), P(5) |
| 18 | 25º 33' 53" | 40º 36' 49" | 1490 | S | 4 | A(5) |
| 19 | 25º 33' 34" | 40º 37' 05" | 1550 | SE | 13 | A(5) |
| 20 | 25º 34' 28" | 40º 37' 29" | 1545 | W | 9 | A(5) |
| 21 | 25º 35' 07" | 40º 37' 38" | 1600 | NW | 10 | A(5) |
| 22 | 25º 35' 34" | 40º 38' 05" | 1620 | E | 15 | A(5) |
| 23 | 25º 35' 06" | 40º 37' 06" | 1570 | S | 2 | A(5) |
| 24 | 25º 34' 57" | 40º 36' 39" | 1540 | E | 8 | A(5) |
| 25 | 25º 36' 00" | 40º 36' 19" | 1495 | S | 14 | A(5), P(6) |
| 26 | 25º 37' 00" | 40º 36' 27" | 1455 | S | 17 | P(5) |
| 27 | 25º 36' 31" | 40º 36' 48" | 1605 | S | 19 | A(5), P(2) |
| **Total** | | | | | | **219** |

*A= *Abies bornmülleriana* Mattf., P=*Pinus sylvestris* L., m= Meter, NE= North East, NW= North West, NE-N= North East-North, SW= South West, SE= South East, W= West, E= East

**Evaluation method:** Regarding the availability of organisms in a place, logistic regression model is being used successfully (Alenius *et al.,* 2002; Syartinilia, 2008). For the distribution models of the lichen species, binary logistic regression model was utilized (Snall *et al*., 2005; Bolliger *et al.,* 2007; Zuur *et al.,* 2007). This model particularly gives an opportunity to significantly predict whether a living organism exists or not (Hosmer & Lemeshow, 2000; Özdamar, 2002). Also, categorical data can be included in the model (Kay & Little, 1987; Bonney, 1987). Logistic regression used in the case of the dependent variable is categorical, or the independent variant, or the both are categorical. Binary logistic regression is used for events that the two-response outputs (Kay & Little, 1987; Bonney, 1987), such as presence or absence of the species in the habitat.

Variables used in the logistic regression are given in Table 2. To determine variables forming model of logistic regression, in the SPSS program forward, step by step, part of the binary logistic regression module is used. $X^2$ and -2LogL statistical models, the selection of the recommended values have been used, whichever is appropriate. Cox and Snell $R^2$ and Nargelkerke $R^2$ statistics even when were used unlike $R^2$ in regression analysis, these statistics can provide information on the variables of the dependent variable rate announcement. The Wald statistics were used for the identification of variables; determined coefficients and significances (Albayrak, 2006). Number of observation of lichen species is calculated that total in each sample trees. Observation classes (tree number) are 1-5, 6-10, 11-20, 21-50, 51-100 and 101 more.

**Table 2. List of variables included in the logistic regression model.**

| Variable | Name | Codes / Values | Abbreviation |
|---|---|---|---|
| | | **Dependent** | |
| Y | Lichen species | Absent:0, Present:1 | LS |
| | | **Independent** | |
| $X_1$ | Tree species | Fir:1, Pine:2 | TS1, TS2 |
| $X_2$ | Stand | Mixed:1, Not-Mixed:2 | FM1, FM2 |
| $X_3$ | Aspect* | Sunny:1, Shady:2 | As1, As2 |
| $X_4$ | Altitude | Meter | Al |
| $X_5$ | Slope | % | S |
| $X_6$ | Tree diameter | cm | TD |
| $X_7$ | Number of lichen species | number | LSN |

* Sunny (As1): W, SE, SW, S, Shady (As2): N NW E

## Results and Discussion

**Relation between model creation and number of observation:** The availability of lichen species in the habitats is in line with the use of logistic regression models. In order to determine species distribution in the study area, the logistic regression models were provided as a result of the analysis of 42 of 82 identified lichen species on 219 trees (Table 3 and 4).

*Ramalina farinacea* species has the highest values for Cox & Snell $R^2$ and Nargelkerke $R^2$; 0.496 and 0.705, respectively, while *Hypogymnia tubulosa* with the lowest values 0.055 and 0.082, respectively (Table 4).

As the number of observation (frequency) increased, the number of species modeled also increased (Table 3). In other words, the more frequent the species are in the area, the higher the number of modeled species. Two of the species, with the number of observation of 6-10 times are modeled (Table 3). Models could not be established for the non-frequent species *Lecanora argentata*, *Usnea hirta*, *Pertusaria coccodes* and *Rinodina exigua*. Also, models could not be established for the species *Hypocoenomyce scalaris*, *Lecanora carpinea*, *Lecanora symmicta* and *Parmelia glabratula* among 11-20 times observed species Similarly, in the 21-50 and 51-100 times observed species, *Ramalina fastigiata* and *Lecidella elaeochroma* models could not be made, because their frequency are too high to be explained by these parameters.

**Evaluation of model variables**

**Number of variables:** The number of variables in logistic regression models changes between 1 and 5 (Tables 4, 5 and 6). Seven variables analyzed from the least to the most as altitude, aspect, slope, tree species, tree diameter, the mixture and number of lichen species.

**Altitude:** The altitude with a direct influence on microclimate, affects the distribution of lichen species. Species richness in the European Alps along the altitudinal gradient was found to be the highest in the upper montane and the lowest in the subalpine belt (Dietrich & Schidegger, 1997). Climatic parameters (e.g. temperature, rainfall, evaporation) are known to be closely related to altitude. The number of lichen species differs with changing habitat related to the elevation (Çobanoğlu & Sevgi, 2009; Öztürk & Güvenç, 2010; Özturk *et al.,* 2010; Oran & Öztürk, 2012). There is a quadratic relationship between the altitude and number of lichen species in places where the difference is 2300 m (400-2700 m) (Pinokiyo *et al*., 2008). Similar relationships were found about the distribution of lichen species and altitude in Malaysia (Zulkifly *et al*., 2011). In the current study, even the elevation difference of only 250 m (1370 m – 1620 m) reduced the species richness.

In the models of *Pertusaria albescens, Pseudevernia furfuracea, Ramalina fraxinea, Schismatomma graphidioides, Cladonia coniocraea, Parmelia submontana, Platismatia glauca* and *Calicium salicinum* species, the altitude is determined as a variable (Tables 5 and 6). Wald values of the altitude variable varies between 3.974 (the lowest, *Calicium salicinum*) and 20.069 (the highest, *Pertusaria albescens*) (Table 6).

**Table 3. Number of species and modeled species according to observation classes.**

| | Observation Classes | | | | | |
|---|---|---|---|---|---|---|
| | **1-5** | **6-10** | **11-20** | **21-50** | **51-100** | **101-more** |
| Number of species | 30 | 6 | 12 | 14 | 14 | 6 |
| Number of modeled species | 0 | 2 | 8 | 13 | 13 | 6 |

**Table 4. Lichen species model highlights.**

| Species | Number of observation | Omnibus tests of model coefficients | | | Model summary | | |
|---|---|---|---|---|---|---|---|
| | | $X^2$ | df | Sig. | 2LL | CS | N |
| *Alectoria sarmentosa* (Ach.) Ach. subsp. *sarmentosa* | 73 | 36.063 | 4 | 0.000 | 242.730 | 0.152 | 0.211 |
| *Bryoria capillaris* (Ach.) Brodo & D.Hawksw | 132 | 74.203 | 4 | 0.000 | 219.848 | 0.288 | 0.390 |
| *Bryoria fuscescens* var. *fuscescens* (Gyeln.) Brodo & D. Hawksw | 37 | 42.425 | 3 | 0.000 | 156.522 | 0.176 | 0.295 |
| *Buellia griseovirens* (Turner & Borrer ex Sm.) Almb. | 64 | 22.183 | 1 | 0.000 | 242.431 | 0.096 | 0.137 |
| *Calicium salicinum* Pers. | 40 | 75.402 | 4 | 0.000 | 132.817 | 0.291 | 0.475 |
| *Calicium viride* Pers. | 17 | 31.697 | 2 | 0.000 | 87.847 | 0.135 | 0.320 |
| *Caloplaca herbidella* (Hue) H.Magn. | 16 | 21.786 | 2 | 0.000 | 92.743 | 0.095 | 0.233 |
| *Chaenotheca chrysocephala* (Turner ex Ach.) Th.Fr. | 21 | 45.028 | 3 | 0.000 | 93.362 | 0.186 | 0.397 |
| *Chrysothrix candelaris* (L.) J.R. Laundon | 48 | 91.146 | 4 | 0.000 | 139.184 | 0.340 | 0.523 |
| *Cladonia coniocraea* (Flörke) Spreng | 59 | 70.064 | 5 | 0.000 | 185.145 | 0.274 | 0.398 |
| *Cladonia fimbriata* (L.) | 23 | 23.968 | 2 | 0.000 | 123.192 | 0.104 | 0.212 |
| *Cyphelium inquinans* (Sm.) Trevis | 14 | 16.847 | 2 | 0.000 | 87.239 | 0.074 | 0.196 |
| *Evernia divaricata* (L.) Ach. | 55 | 13.694 | 2 | 0.001 | 233.157 | 0.061 | 0.090 |
| *Evernia prunastri* (L.) Ach. | 17 | 29.124 | 2 | 0.000 | 90.420 | 0.125 | 0.296 |
| *Graphina ruiziana* (Fée) Müll.Arg. | 31 | 25.722 | 2 | 0.000 | 152.882 | 0.111 | 0.199 |
| *Hypogymnia physodes* (L.) Nyl. | 188 | 23.218 | 4 | 0.000 | 155.386 | 0.101 | 0.180 |
| *Hypogymnia tubulosa* (Schaer.) Hav. | 53 | 12.305 | 1 | 0.000 | 230.077 | 0.055 | 0.082 |
| *Lecanora chlarotera* Nyl. | 36 | 24.489 | 3 | 0.000 | 171.240 | 0.106 | 0.179 |
| *Lecanora pallida* (Schreb.) Rabenh. | 27 | 35.711 | 2 | 0.000 | 127.849 | 0.150 | 0.286 |
| *Lobaria pulmonaria* (L.) Hoffm. | 19 | 11.716 | 1 | 0.001 | 117.482 | 0.052 | 0.117 |
| *Ochrolechia parella* (L.) A.Massal. | 6 | 21.432 | 3 | 0.000 | 33.570 | 0.093 | 0.420 |
| *Ochrolechia turneri* (Sm.) Hasselrot | 57 | 58.757 | 3 | 0.000 | 192.368 | 0.235 | 0.345 |
| *Opegrapha atra* Mont. | 59 | 107.483 | 3 | 0.000 | 147.726 | 0.388 | 0.564 |
| *Parmelia saxatilis* (L.) Ach. | 92 | 100.671 | 3 | 0.000 | 184.816 | 0.404 | 0.543 |
| *Parmelia submontana* Nadv. ex Hale | 21 | 21.054 | 3 | 0.000 | 117.336 | 0.092 | 0.196 |
| *Parmelia sulcata* Taylor | 14 | 31.895 | 3 | 0.000 | 72.191 | 0.136 | 0.358 |
| *Parmeliopsis ambigua* (Wulfen) Nyl. | 144 | 64.918 | 4 | 0.000 | 216.566 | 0.257 | 0.355 |
| *Pertusaria albescens* var. *albescens* (Huds.) M.Choisy & Werner | 81 | 88.878 | 2 | 0.000 | 199.713 | 0.334 | 0.456 |
| *Pertusaria amara* (Ach.) Nyl. | 62 | 23.671 | 2 | 0.000 | 237.316 | 0.102 | 0.147 |
| *Pertusaria hemisphaerica* (Flörke) Erichsen | 27 | 12.782 | 1 | 0.000 | 150.778 | 0.057 | 0.108 |
| *Platismatia glauca* (L.) W.L. Culb. & C.F. Culb. | 91 | 22.724 | 3 | 0.000 | 274.593 | 0.099 | 0.133 |
| *Pseudevernia furfuracea* var. *furfuracea* (L.) Zopf | 72 | 150.828 | 5 | 0.000 | 126.559 | 0.498 | 0.693 |
| *Ramalina farinacea* (L.) Ach. | 154 | 149.949 | 3 | 0.000 | 116.412 | 0.496 | 0.705 |
| *Ramalina fraxinea* (L.) Ach. | 19 | 12.054 | 1 | 0.001 | 117.144 | 0.054 | 0.120 |
| *Ramalina thrausta* (Ach.) Nyl. | 45 | 41.793 | 3 | 0.000 | 180.670 | 0.174 | 0.272 |
| *Schismatomma graphidioides* (Leight.) Zahlbr. | 36 | 69.911 | 4 | 0.000 | 125.817 | 0.273 | 0.463 |
| *Tuckermanopsis chlorophylla* (Wild.) Hale | 150 | 66.334 | 2 | 0.000 | 206.582 | 0.261 | 0.368 |
| *Usnea filipendula* Stirt. | 46 | 41.078 | 2 | 0.000 | 184.061 | 0.171 | 0.266 |
| *Usnea florida* (L.) Weber ex F.H. Wigg. | 84 | 31.350 | 3 | 0.000 | 260.262 | 0.133 | 0.181 |
| *Usnea fulvoreagens* (Rasanen) Rasanen | 10 | 18.925 | 2 | 0.000 | 62.341 | 0.083 | 0.267 |
| *Usnea subfloridana* Stirt. | 142 | 64.082 | 4 | 0.000 | 219.931 | 0.254 | 0.349 |
| *Usnea subscabrosa* Nyl. ex Motyka | 19 | 8.458 | 1 | 0.004 | 120.740 | 0.038 | 0.085 |

**Table 5. Values of variable coefficients.**

| | Constant | Mixed forest (FM) | Tree species (TS1) | Tree diameter (TD) | Number of lichen species | Altitude (AL) | Slope (S) | Aspect (As1) |
|---|---|---|---|---|---|---|---|---|
| *Alectoria sarmentosa* | -0.804 | -0.851** | -1.437** | | 0.190*** | | -0.077** | |
| *Bryoria capillaris* | 0.751 | | -3.186*** | -0.041*** | 0.253*** | | | 1.063** |
| *Bryoria fuscescens* | -4.887*** | 1.726*** | -1.804*** | | 0.277*** | | | |
| *Buellia griseovirens* | -2.983*** | | | | 0.165*** | | | |
| *Calicium salicinum* | 6.876 | -2.234*** | | 0.051*** | 0.235*** | -0.008* | | |
| *Calicium viride* | -7.511*** | | | 0.054*** | 0.193** | | | |
| *Caloplaca herbidella* | -4.710*** | | | -0.600** | 0.289*** | | | |
| *Chaenotheca chrysocephala* | -6.299*** | -2.531* | | 0.028* | 0.242*** | | | |
| *Chrysothrix candelaris* | -6.144*** | -2.936*** | | 0.049*** | 0.219*** | | 0.079* | |
| *Cladonia coniocraea* | 12.668* | | | 0.059*** | 0.149*** | -0.012*** | 0.074* | -1.014* |
| *Cladonia fimbriata* | -4.148*** | | -2.398*** | | 0.278*** | | | |
| *Cyphelium inquinans* | -3.983*** | -1.512* | | 0.042** | | | | |
| *Evernia divaricata* | -2.901*** | | | | 0.091* | | 0.060* | |
| *Evernia prunastri* | -7.809*** | 3.144*** | | | 0.240*** | | | |
| *Graphina ruiziana* | -0.486 | -2.249*** | | | | | -0.078* | |
| *Hypogymnia physodes* | 4.364*** | | -3.100** | -0.022* | 0.155** | | | -1.148* |
| *Hypogymnia tubulosa* | -2.751*** | | | | 0.126*** | | | |
| *Lecanora chlarotera* | -4.949*** | 1.409*** | | | 0.128** | | | 1.161* |
| *Lecanora pallida* | -6.905*** | 1.523** | | | 0.300*** | | | |
| *Lobaria pulmonaria* | -1.802*** | -2.080** | | | | | | |
| *Ochrolechia parella* | -11.110*** | -3.592* | | | 0.208* | | 0.350*** | |
| *Ochrolechia turneri* | -1.590* | | -3.393*** | | 0.297*** | | -0.075** | |
| *Opegrapha atra* | -2.152** | -3.706*** | | | 0.255*** | | -0.136*** | |
| *Parmelia saxatilis* | -1.289* | -2.249*** | | | 0.245*** | | -0.118*** | |
| *Parmelia submontana* | 25.173** | -2.134** | | | | -0.017*** | | -1.745** |
| *Parmelia sulcata* | -8.317*** | 3.661*** | | | 0.312*** | | | -1.739* |
| *Parmeliopsis ambigua* | 1.694** | | -3.599*** | 0.021* | 0.184*** | | | -1.111** |
| *Pertusaria albescens* | -32.141*** | | | | 0.288*** | 0.018*** | | |
| *Pertusaria amara* | -1.669* | | 2.340*** | | -0.107** | | | |
| *Pertusaria hemisphaerica* | -1.439*** | -1.728** | | | | | | |
| *Platismatia glauca* | -11.394** | | -1.520*** | | 0.105** | 0.007** | | |
| *Pseudevernia furfuracea* | -23.911*** | 3.648*** | -5.347*** | -0.060*** | 0.268*** | 0.016*** | | |
| *Ramalina farinacea* | -7.933*** | 1.620* | 6.392*** | | 0.273*** | | | |
| *Ramalina fraxinea* | 16.151** | | | | | -0.012*** | | |
| *Ramalina thrausta* | -4.620*** | -1.070** | | | 0.208*** | | | 1.205* |
| *Schismatomma graphidioides* | 22.764** | -2.156*** | | | 0.377*** | -0.018*** | | -1.556** |
| *Tuckermannopsis chlorophylla* | -3.308*** | | 1.373*** | | 0.274*** | | | |
| *Usnea filipendula* | -4.199*** | | | -0.025* | 0.278*** | | | |
| *Usnea florida* | -3.581*** | 1.244*** | 1.808*** | | 0.084* | | | |
| *Usnea fulvoreagens* | -8.711*** | 2.532** | | | 0.289*** | | | |
| *Usnea subfloridana* | -2.180*** | 1.381*** | | -0.019* | 0.320*** | | -0.079** | |
| *Usnea subscabrosa* | -3.563*** | | | | | | 0.098** | |

**Slope:** The slope, relating the duration and amount of sun affects the distribution of lichen species (Çobanoğlu & Sevgi, 2009). In the research area, the fifth sample site has the maximum slope of 55%. Due to the low differentiation of slope in the area, the slope variable could enter only 11 models with the species; *Parmelia saxatilis, Opegrapha atra, Ochrolechia parella, Usnea subfloridana, Usnea subscabrosa, Alectoria sarmentosa, Evernia divaricata, Ochrolechia turneri, Cladonia coniocraea, Chrysotrix candelaris* and *Graphina ruiziana*. In the models where slope enters as a variable, the Wald values range between the lowest of 3.990 (*Graphina ruiziana*) and the highest of 14.348 (*Parmelia saxatilis*) (Table 6).

**Aspect:** The aspect, due to being directly related to the sun exposure (light, temperature, evaporation), affects the distribution of lichen species (Barkman, 1958). The difference would be created by the aspect which is thought to be reduced due to the low elevation difference and the low slope in the study area. The aspect of stand as a variable has been accounted into 9 models, and the species are *Bryoria capillaris*, *Parmeliopsis ambigua, Parmelia submontana, Schismatomma graphidioides, Ramalina thrausta, Parmelia sulcata, Hypogymnia physodes, Cladonia coniocraea* and *Lecanora chlarotera*. The Wald values of the variable range between the lowest value 4.175 in *Lecanora chlarotera* and the highest value 9.079 in *Bryoria capillaris* (Table 6).

**Tree species:** Change of tree species affects the distribution of genus communities, which further affects the distribution of lichen species (McCune *et al*., 2000). The distribution of some lichen species was affected due to differences attributing to the bark characteristics of fir and pine species. The number of micro lichen species was found to be significantly higher in pine forests than in deciduous forests, and similarly for bark (Ihlen *et al*., 2001). The number of lichen species varies according to different tree species. For instance, 471 trees from 95 sample plots were sampled and a total of 37 epiphytic lichen taxa were recorded on the barks in black pine forest (*Pinus nigra* Arn.) (Çobanoğlu *et al*., 2011), while in a cedar forest (*Cedrus libani*), 54 species were identified on 119 trees (Çobanoğlu & Sevgi, 2006).

**Table 6. The wald values.**

| | Constant | Mixed forest (FM) | Tree species (TS1) | Tree diameter (TD) | Number of lichen species | Altitude (AL) | Slope (S) | Aspect (As1) |
|---|---|---|---|---|---|---|---|---|
| *Alectoria sarmentosa* | 1.542 | 5.460 | 8.604 | | 19.979 | | 8.231 | |
| *Bryoria capillaris* | 1.011 | | 26.523 | 14.801 | 27.195 | | | 9.079 |
| *Bryoria fuscescens* | 29.280 | 11.923 | 10.203 | | 21.257 | | | |
| *Buellia griseovirens* | 33.835 | | | | 19.842 | | | |
| *Calicium salicinum* | 1.160 | 12.242 | | 14.509 | 17.087 | 3.974 | | |
| *Calicium viride* | 36.150 | | | 12.373 | 9.206 | | | |
| *Caloplaca herbidella* | 20.809 | | | 7.016 | 15.201 | | | |
| *Chaenotheca chrysocephala* | 27.051 | 5.731 | | 4.175 | 12.566 | | | |
| *Chrysothrix candelaris* | 34.426 | 19.431 | | 14.155 | 16.229 | | 4.496 | |
| *Cladonia coniocraea* | 5.313 | | | 25.922 | 10.726 | 10.501 | 6.142 | 4.898 |
| *Cladonia fimbriata* | 27.999 | | 12.413 | | 16.831 | | | |
| *Cyphelium inquinans* | 29.939 | 3.659 | | 9.691 | | | | |
| *Evernia divaricata* | 26.234 | | | | 6.359 | | 6.475 | |
| *Evernia prunastri* | 30.612 | 13.855 | | | 12.640 | | | |
| *Graphina ruiziana* | 1.511 | 12.798 | | | | | 3.990 | |
| *Hypogymnia physodes* | 12.449 | | 8.487 | 4.120 | 8.348 | | | 5.117 |
| *Hypogymnia tubulosa* | 28.391 | | | | 11.702 | | | |
| *Lecanora chlarotera* | 31.171 | 10.571 | | | 7.806 | | | 4.175 |
| *Lecanora pallida* | 41.556 | 8.960 | | | 25.701 | | | |
| *Lobaria pulmonaria* | 47.357 | 7.475 | | | | | | |
| *Ochrolechia parella* | 13.195 | 5.392 | | | 3.891 | | 10.195 | |
| *Ochrolechia turneri* | 6.414 | | 35.737 | | 28.290 | | 6.371 | |
| *Opegrapha atra* | 8.666 | 23.613 | | | 22.278 | | 10.476 | |
| *Parmelia saxatilis* | 4.593 | 34.885 | | | 26.027 | | 14.348 | |
| *Parmelia submontana* | 9.182 | 9.212 | | | | 10.149 | | 8.147 |
| *Parmelia sulcata* | 26.940 | 13.945 | | | 14.936 | | | 5.841 |
| *Parmeliopsis ambigua* | 3.519 | | 21.034 | 4.124 | 16.362 | | | 8.596 |
| *Pertusaria albescens* | 25.381 | | | | 37.605 | 20.069 | | |
| *Pertusaria amara* | 5.939 | | 13.501 | | 7.691 | | | |
| *Pertusaria hemisphaerica* | 38.510 | 9.504 | | | | | | |
| *Platismatia glauca* | 7.706 | | 14.121 | | 8.413 | 6.874 | | |
| *Pseudevernia furfuracea* | 13.697 | 39.677 | 34.044 | 10.846 | 16.070 | 13.327 | | |
| *Ramalina farinacea* | 29.120 | 5.850 | 29.286 | | 14.614 | | | |
| *Ramalina fraxinea* | 9.672 | | | | | 12.391 | | |
| *Ramalina thrausta* | 32.573 | 6.587 | | | 20.400 | | | 6.544 |
| *Schismatomma graphidioides* | 8.461 | 10.255 | | | 29.237 | 12.367 | | 7.151 |
| *Tuckermannopsis chlorophylla* | 28.848 | | 11.930 | | 25.348 | | | |
| *Usnea filipendula* | 36.689 | | | 4.463 | 30.991 | | | |
| *Usnea florida* | 30.162 | 13.720 | 13.214 | | 5.398 | | | |
| *Usnea fulvoreagens* | 24.797 | 7.889 | | | 11.673 | | | |
| *Usnea subfloridana* | 10.436 | 13.936 | | 3.949 | 37.842 | | 9.158 | |
| *Usnea subscabrosa* | 43.535 | | | | | | 8.406 | |

In the study area, on 175 fir trees (*Abies bornmülleriana* Mattf., the dominant tree species,) 80 lichen species were found, while 43 species of lichen were determined in the 44 pine trees (*Pinus sylvestris* L.) (Table 1). The number of tree species as a variable was modelled at 13 lichen species which are *Ochrolechia turneri, Pseudevernia furfuracea, Ramalina farinacea, Bryoria capillaris, Parmeliopsis ambigua, Platismatia glauca, Pertusaria amara, Usnea florida, Cladonia fimbriata, Tuckermannopsis chlorophylla, Bryoria fuscescens, Alectoria sarmentosa* and *Hypogymnia physodes* (Table 6). The Wald values of the variable range between the lowest value of 8.487 in *Hypogymnia physodes* and the highest value of 35.737 in *Ochrolechia turneri* (Table 6).

**Tree diameter:** Tree diameter, causing change in physical and chemical properties of bark, affects the allocation of lichen species. Stevenson & Enns (1993) stated that both the numbers of individual lichens and surface areas of lichens were correlated with tree diameter (r= 0.867-0.880). Hedenas & Ericson (2000) noted that many species showed positive relationship with increasing mean diameter while some others showed a negative relationship with mean diameter. In the present study, we observed the effect of tree diameter on the distribution and composition of number of lichen species. Similar results were found in the recent studies (Stevenson & Enns, 1993; Rolstad & Rolstad, 1999; Hedenas & Ericson, 2000; Kantvillas & Jarman, 2004). Our results showed that the relationship between diameter classes with the number of lichen species was $R^2$=0.60 (Çobanoğlu & Sevgi, 2009). The lichen species in the models in which tree diameter is used as a variable are *Cladonia coniocraea, Bryoria capillaris, Calicium salicinum, Chrysothrix candelaris, Calicium viride, Pseudevernia furfuracea, Cyphelium inquinans, Caloplaca herbidella, Usnea filipendula, Chaenotheca chrysocephala, Parmeliopsis ambigua, Hypogymnia physodes* and *Usnea subfloridana* (Table 5). The Wald values of the variable range between the lowest value of 3.949 in *Usnea subfloridana* and the highest value of 25.922 in *Cladonia coniocraea* (Table 6).

**Forest mixed:** Forest texture, affecting the microclimate in stand, and having an influences on the distribution of lichen species. The forest mixed as a variable enters 24 models with the species; *Pseudevernia furfuracea, Parmelia saxatilis, Opegrapha atra, Chrysothrix candelaris, Parmelia sulcata, Usnea subfloridana, Evernia prunastri, Usnea florida, Graphina ruiziana, Calicium salicinum, Bryoria fuscescens, Lecanora chlarotera, Schismatomma graphidioides, Pertusaria hemisphaerica, Parmelia submontana, Lecanora pallida, Usnea fulvoreagens, Lobaria pulmonaria, Ramalina* *thrausta, Ramalina farinacea, Chaenotheca chrysocephala, Alectoria sarmentosa, Ochrolechia parella* and *Cyphelium inquinans* (Table 5).

**Lichen species number:** As the logistic models are based on the maximum likelihood, the number of species increases when the probability of encountering lichen increases. However, due to some of these species being present with the increasing number of lichen species; it is also possible to say that these species come to the environment later. On the contrary, it is possible to say the mentioned species are pioneer lichen species. In this study, lichen species where "lichen species number" as variable is appropriate are as follows; *Usnea subfloridana, Pertusaria albescens, Usnea filipendula, Schismatomma graphidioides, Ochrolechia turneri, Bryoria capillaris, Parmelia saxatilis, Lecanora pallida, Tuckermannopsis chlorophylla, Opegrapha atra, Bryoria fuscescens, Ramalina thrausta, Alectoria sarmentosa, Buellia griseovirens, Calicium salicinum, Cladonia fimbriata, Parmeliopsis ambigua, Chrysothrix candelaris, Pseudevernia furfuracea, Caloplaca herbidella, Parmelia sulcata, Ramalina farinacea, Evernia prunastri, Chaenotheca chrysocephala, Hypogymnia tubulosa, Usnea fulvoreagens, Cladonia coniocraea, Calicium viride, Platismatia glauca, Hypogymnia physodes, Lecanora chlarotera, Pertusaria amara, Evernia divaricata, Usnea florida* and *Ochrolechia parella* (Table 5). The Wald values of the variable range between 3.891 the lowest value in *Ochrolechia parella* and the highest value 37.842 in *Usnea subfloridana* (Table 6).

## Conclusion

Evaluation of the results obtained by application of logistic regression models and variable coefficients of 42 epiphytic lichen species showed that the variables such as stand mixture, tree species, tree diameter and lichen species number were more expressive than the others in the study area.

The number of observation of a lichen species in the study area is an important determinant factor for modeling. For example, the lichen species in which the logistic models could not be established had 5 or less observation numbers. *Ramalina farinacea* had the highest value for Cox and Snell $R^2$ and Nargelkerke $R^2$, respectively 0.496 and 0.705. The reason of number modeling for the species with a larger number of observation, *Ramalina fastigiata* and *Lecidella elaeochroma*, may be unexplained with the variables which are subject of the study. New variables should be measured in order to establish models of these species.

Due to small differences in the elevations and in the slopes of the study area, effects of the aspect decreased. Therefore, habitat is considered to show no significant differences in terms of these variables. However, the variables that are more often used are; pure or mixed stand, tree species, tree diameter and number of lichen species in such models. These models need to be tested in other habitats also. Model variables to resolve the differences should be obtained from the general model. Thus, these models can be used for estimation of which lichens are found in various habitats.

It is concluded that the regression models created in the present study are significant and can be successfully implemented for the investigation of distribution of lichens in a forest ecosystem with the effects of ecological variables. Also, in studies such as biodiversity and pollution indication of an area, it will be possible to use these lichen distribution models.

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