http://dergipark.org.tr/tr/pub/anatolianbryology

DOI: 10.26672/anatolianbryology.1594697

Anatolian Bryology
Anadolu Briyoloji Dergisi
*Research Article*
e-ISSN:2458-8474
Online

# Environmental and Topographical Factors Influencing Moss Distribution in Semi-Arid Regions: A Study of Çankırı-Eldivan Mountain

**Serhat URSAVAŞ[1], Semih EDİŞ[1]***

[1]*University of Çankırı Karatekin, Faculty of Forestry, Department of Forest Engineering, Çankırı, TÜRKİYE*

**Received: 02 December 2024** **Revised: 04 December 2024** **Accepted: 04 December 2024**

**Abstract**

This research investigated the environmental and topographical variables influencing the distribution of moss, utilizing data from 455 sampling locations in the Çankırı-Eldivan Mountain region. Logistic regression analysis results indicated that the primary determinants of moss presence were elevation, mean temperature, and slope. Elevation positively influences moss presence, whereas mean temperature negatively affects it. Slope, conversely, positively influenced moss habitats by enhancing water retention and soil stability. Despite the limited impact of the aspect, surfaces oriented towards the north and east were more advantageous. The total precipitation positively influenced moss presence; however, this effect was eclipsed by elevation. These findings significantly enhance the comprehension of mosses' ecological tolerance and reliance on environmental variables. The research underscores critical environmental variables influencing moss distribution and establishes a foundation for natural resource management, biodiversity conservation strategies, and evaluation of climate change impacts. Future research should investigate anthropogenic influences on moss distribution more comprehensively and employ molecular ecological techniques.

**Keywords:** Microclimate, Ecosystem, Topography, Adaptation, Bryophyte, Türkiye

## Yarı Kurak Bölgelerde Karayosunu Varlığını Etkileyen Çevresel ve Topoğrafik Değişkenler: Çankırı-Eldivan Dağı Örneği

**Öz**

Bu çalışma, Çankırı-Eldivan Dağı'ndaki 455 örnekleme noktasından elde edilen veriler kullanılarak karayosunu varlığını etkileyen çevresel ve topoğrafik faktörleri incelemektedir. Lojistik regresyon analizi sonuçları, karayosunu varlığını belirleyen en güçlü faktörlerin yükselti, ortalama sıcaklık ve eğim olduğunu göstermiştir. Yükselti, karayosunu varlığı üzerinde pozitif bir etkiye sahipken, ortalama sıcaklık negatif bir etki göstermektedir. Eğim ise su birikimi ve toprak stabilitesini destekleyerek karayosunu habitatlarını olumlu yönde etkilemiştir. Bakı değişkeni sınırlı bir etki gösterse de kuzey ve doğu yönelimli yüzeylerin daha avantajlı olduğu belirlenmiştir. Toplam yağışın karayosunu varlığı üzerinde pozitif bir etkisi olduğu tespit edilmiştir, ancak bu etkinin yükseltinin gölgesinde kaldığı görülmüştür. Bu bulgular, karayosunlarının ekolojik toleranslarını ve çevresel değişkenlere olan bağımlılıklarını anlamada önemli katkılar sağlamaktadır. Çalışma, karayosunlarının dağılımını etkileyen temel çevresel faktörleri vurgularken, doğal kaynak yönetimi, biyoçeşitlilik koruma stratejileri ve iklim değişikliğinin etkilerini değerlendirmek için bir temel sunmaktadır. Gelecekteki çalışmalar, karayosunu dağılımını etkileyen insan kaynaklı faktörlerin daha detaylı bir şekilde incelenmesini ve moleküler ekoloji yaklaşımlarının kullanılmasını önermektedir.

**Anahtar kelimeler:** Mikroklima, Ekosistem, Topografya, Adaptasyon, Briyofit, Türkiye

* Corresponding author: semihedis@karatekin.edu.tr

To cite this article: *Ursavaş S. Ediş S. 2024. Environmental and Topographical Factors Influencing Moss Distribution in Semi-Arid Regions: A Study of Çankırı-Eldivan Mountain. Anatolian Bryology. 10:2, 179-190.*

## 1. Introduction

Mosses are prevalent in terrestrial ecosystems, and their presence and distribution result from the interaction of environmental and geographical processes and phenomena. These encompass climate, soil types and processes, topography, and biotas that collectively influence the habitats in which mosses are located. Mosses exhibit remarkable adaptability, thrive in habitats ranging from arid deserts to verdant forests and urban settings. Understanding moss ecology necessitates an examination of the influences of temperature, precipitation, soil chemistry, and topography (Alataş et al. 2023).

Temperature and precipitation are the primary determinants of moss distribution among the climatic factors. In Qinhuangdao, China, the annual temperature range significantly influences the composition of moss communities (Zheng et al., 2024). In the Gurbantunggut Desert, average annual temperature and precipitation are critical factors influencing moss growth (Ji et al., 2018). Additionally, variables such as light intensity and solar radiation affect moss diversity. Despite the harsh conditions in Antarctica, mosses exhibit adaptation to microclimatic regions, utilizing optimal light conditions for photosynthesis (Yin et al., 2023). The soil characteristics significantly affect the occurrence of mosses. Soil chemistry, especially pH, mineral content and cation exchange capacity, are essential parameters that favor moss development (Perdrizet and McKnight, 2012; Abay et. al., 2014; Abay et. al., 2015). In Changbai Mountain, the primary edaphic factors influencing moss distribution are soil sand content and soil acidity (Shui-Liang and Tong, 2001). Moreover, soil moisture significantly influences moss presence and ecosystem processes in desert and Arctic regions (Gornall et al., 2007).

Topographic and geographic factors significantly influence the spatial distribution of mosses. As demonstrated by numerous studies (Shui-Liang and Tong, 2001), altitude significantly influences the distribution patterns of moss taxa. Latitude is a significant factor influencing the development of moss colonies, particularly in Central Asia (Ji et al., 2018). Moreover, habitat heterogeneity enhances moss diversity in regions such as South Africa, where specific areas are recognized as biodiversity hotspots (Rooy and Phephu, 2016).

Biotic interactions and anthropogenic activities significantly influence moss ecology. The existence of specific vegetation and tree species influences epiphytic moss communities (Perdrizet and McKnight, 2012). Mosses inhabit diverse surfaces in urban environments, adjusting to light, humidity, and temperature conditions modified by human activity (Cruz et al., 2023). Moreover, disturbance can influence both the presence of moss and ecosystem processes, thereby modifying ecological functioning, mainly through changes in soil temperature and moisture equilibrium (Gornall et al., 2007).

Mosses have significant ecological functions in ecosystems from tropical to polar regions. Their roles in carbon and nitrogen cycling, the ability to enhance soil properties, and regulation of water dynamics are essential for ecosystem stability and resilience. Mosses in boreal ecosystems establish symbiotic associations with nitrogen-fixing cyanobacteria, influencing the nitrogen cycle and aiding in carbon fixation (Alvarenga and Rousk, 2022). Moreover, their ability to retain soil moisture and diminish evaporation is crucial for sustaining soil carbon reserves (Shidong et al., 2019).

Mosses facilitate the accumulation of soil carbon and nitrogen in ecosystem restoration by affecting soil microbial communities and properties. This aids in the restoration of ecosystems, particularly in compromised regions (Xiao et al., 2023). The resilience of mosses to environmental disturbances and ability to adapt to varying conditions are essential for ecosystem functionality. The potential effects of climate change and land use alterations on these ecosystems constitute a vital domain for future research (Gonzalez-Aragon et al., 2024). Understanding these dynamics is essential for formulation of conservation and management strategies.

The primary aim of this study was to identify the environmental and geographical factors influencing moss presence and to evaluate their relative effects on moss ecology. Mosses exhibit heightened sensitivity to microclimatic conditions as a group of plants integral to ecosystem functionality. Consequently, comprehending the impact of environmental factors such as slope, aspect, elevation, temperature, and precipitation on the development of moss habitats is essential for analyzing ecosystem dynamics and enhancing natural resource management strategies. This study sought to examine the principal factors that facilitate the existence of black moss in a particular geographic area. The study aims to ascertain the impact of variables including slope, aspect, elevation, rainfall, and temperature on the prevalence of moss and to elucidate the relative significance of these effects.

- To create an ecological model capable of predicting moss presence.
- To juxtapose the study's findings with the current ecological literature to provide new insights and enhance the knowledge.
- To propose sustainable strategies for managing and conserving moss habitats through the application of collected data.

## 2. Materials and Methods

### *2.1. Research area and sampling design*

The research was conducted in Eldivan Mountain, situated in Çankırı province (Figure 1). The study area provides an appropriate setting for examining the distribution of mosses owing to its geographical and topographical diversity. The sampling areas were structured as a grid with a spacing of 300x300 m, resulting in a total of 455 sampling points established. The procedure was executed using ArcGIS 10.6.1 software. The geographical attributes of the locations, particularly topographic variables including slope, aspect, and elevation, were examined in an office setting.

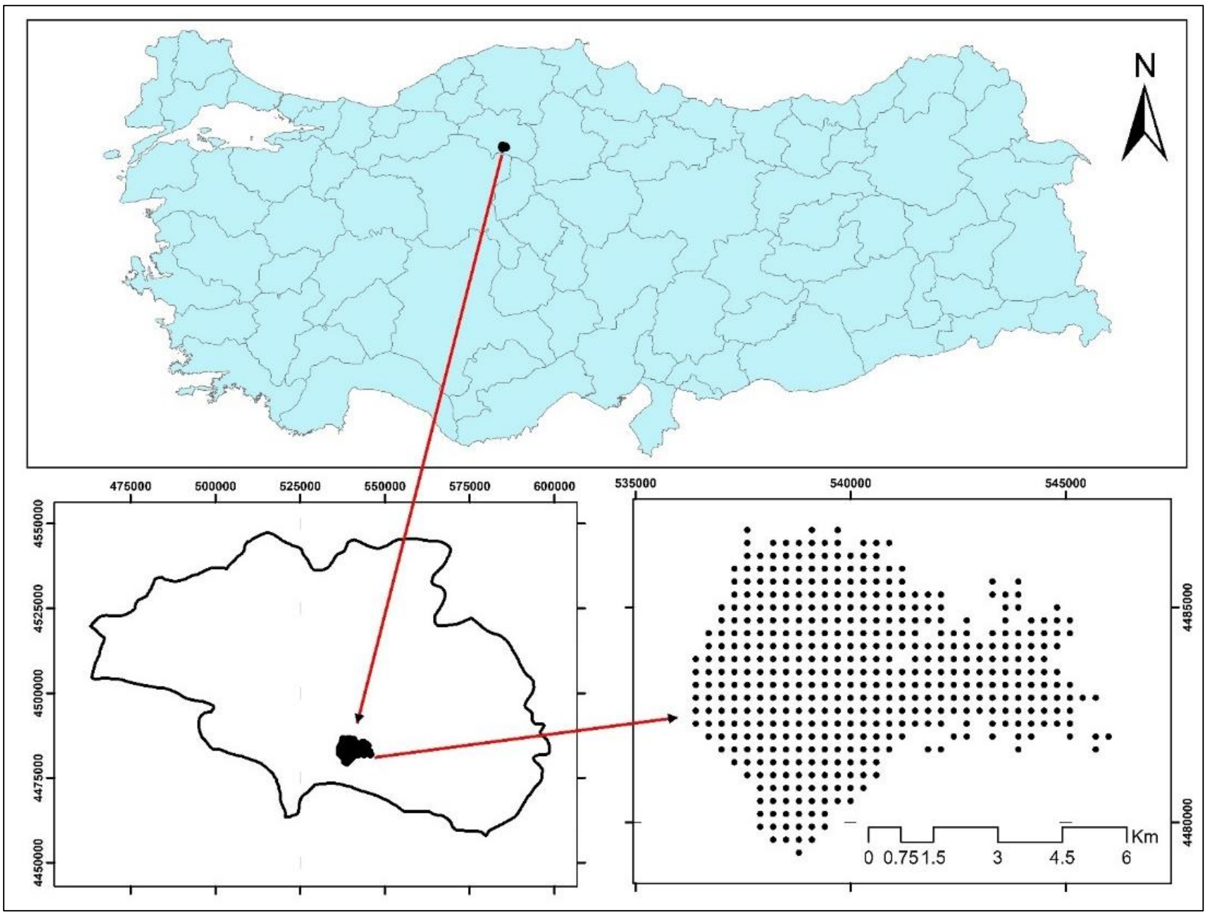


Figure 1. Location of the study area.

### *2.2. Sampling design*

During the field surveys, a 2x2 m grid system was implemented at each sampling location, and the occurrence of mosses within the grid was documented. This method standardized sampling density and facilitated a more precise assessment of plant presence at the microhabitat level.

### *2.3. Acquisition of meteorological data*

Mean precipitation, total precipitation, and mean temperature values for each sampling location were obtained from data sourced from the Çankırı Meteorological Station (MGM, 2024). The spatial distribution of meteorological variables was interpolated using specific elevation values from individual points. The Schreiber method (Schreiber, 1904) was employed for the interpolation of precipitation data, whereas the Lapse Rate method (Rolland, 2003) was utilized for the interpolation of temperature data. These methods are predominantly favored for the accurate modeling of climatic variations at various altitudes.

### *2.4. Statistical analyzes*

Statistical analyses were performed to find environmental variables influencing the occurrence of mosses. First, correlation analysis was performed to evaluate the associations among variables (Pearson, 1895). Then logistic regression was applied for the binary moss variable (present/absent; Hosmer and Lemeshow, 2000). This method is appropriate to evaluate the probability of dependent variable presence, constituting a quantitative assessment of the relative effect of environmental variables. The logistic regression model used to estimate the presence of moss is described in equation 1.

$$P(Y=1) = \frac{1}{1+e^{-(\beta 0+\beta 1x1+\beta 2x2+\ldots\beta nxn)}} \quad \text{(Eq. 1)}$$

P(Y=1): Probability of moss presence
$\beta_0$: Constant coefficient
$\beta_1,\ldots\beta_n$: Regression coefficients of independent variables
$X_1, \ldots. X_n$: Independent variables
$e$: Natural logarithm base

The accuracy of the model's predictions was evaluated using ROC curve analysis, following the methodology of Hanley and McNeil (1982). Descriptive statistics were computed using SPSS 22 and R software. Several statistical analyses were conducted to determine which environmental variables were influencing the presence of black seaweed. Initially, Pearson correlation coefficients were calculated to assess the relationships among independent variables. A logistic regression analysis was performed to examine the relationship between the dependent variable (presence or absence of moss) and various environmental factors to identify those most significantly associated with moss presence. The significance of these factors was assessed using p-values, and the explained variability was evaluated using Nagelkerke $R^2$. The detection performance was also analyzed through ROC curve analysis and calculation of the Area Under the Curve (AUC).

## 3. Results and Discussion

Upon analysis of the data, it was noted that the coefficient of variation for the slope and aspect variables was 49.26% and 71.33%, respectively, signifying a high degree of variability in these variables. The reduced coefficients of variation in altitude and precipitation variables (12.26% and 2.31%) suggest that these variables exhibit a more stable structure. The mean temperature varied by 18.14%, the maximum temperature by 7.36%, and the minimum temperature by 43.52%. A significant variation of 65.99% was noted in the presence of moss (Table 1). The findings indicate that the distribution is broad for certain variables and more constrained for others.

Table 1. Descriptive statistics of the variables

| | Slope | Aspect | Elevation | Mean Prec. | Total Prec. | Mean Temp. | Max Temp. | Min Temp. | Moss Presence |
|---|---|---|---|---|---|---|---|---|---|
| **Count** | 455 | 455 | 455 | 455 | 455 | 455 | 455 | 455 | 455 |
| **Mean** | 30.04 | 167 | 1319.84 | 37.76 | 453.1 | 8.33 | 19.63 | -3.96 | 0.69 |
| **Std** | 14.8 | 119 | 161.84 | 0.87 | 10.49 | 1.51 | 1.44 | 1.72 | 0.46 |
| **Min** | 0.0 | -1.0 | 1000.0 | 36.03 | 432.38 | 4.27 | 15.74 | -8.59 | 0.0 |
| **0,25** | 18.14 | 60 | 1194.5 | 37.08 | 444.98 | 7.18 | 18.53 | -5.27 | 0.0 |
| **0,50** | 28.92 | 137 | 1318.0 | 37.75 | 452.98 | 8.35 | 19.64 | -3.94 | 1.0 |
| **0,75** | 39.01 | 295 | 1443.0 | 38.42 | 461.08 | 9.5 | 20.75 | -2.62 | 1.0 |
| **Max** | 88.06 | 358 | 1755.0 | 40.11 | 481.3 | 11.32 | 22.48 | -0.55 | 1.0 |
| **Skewness** | 0.62 | 0.28 | 0.15 | 0.15 | 0.15 | -0.15 | -0.15 | -0.15 | -0.85 |
| **Kurtosis** | 0.41 | -1.38 | -0.69 | -0.69 | -0.69 | -0.69 | -0.69 | -0.69 | -1.27 |
| **CV (%)** | 49.26 | 71 | 12.26 | 2.31 | 2.31 | 18.13 | 7.36 | 43.52 | 66 |

CV: Coefficient of variations (%).

The logistic regression analysis results from the study indicated the relative impact of environmental variables on moss presence. The analyses indicated that elevation, mean temperature, and slope were the most significant variables affecting moss distribution. These findings offer significant insights into moss's ecological niche and its susceptibility to environmental conditions.

### *3.1. Variables with the most significant influence*

The presence of moss was most significantly influenced by elevation ($p < 0.001$). The likelihood of moss occurrence increases with increasing elevation. This outcome aligns with existing literature indicating that humid microclimatic conditions at elevated altitudes are more conducive to moss growth (Bates, 2000). The humid conditions, resulting from reduced temperatures and diminished evaporation, enhance the water retention capacity of mosses and facilitate their survival.

The mean temperature was a significant factor that negatively affecting moss presence ($p < 0.01$). It was noted that low temperatures enhance the metabolic activities of mosses, resulting in a diminished likelihood of moss presence as temperatures rise. This aligns with prior research indicating that elevated temperatures enhance water loss, constraining moss growth (Rydin, 2009).

The slope was another critical factor ($p < 0.05$) influencing water retention, soil stability, and the moss presence. Mosses were more prevalent in regions with moderate slopes (10% - 30%). These regions have established conditions for moss habitats by facilitating water accumulation and moisture retention.

### *3.2. Impact scores of variables*

The graph illustrates the impact of elevation, temperature, and slope variable on moss presence (Figure 2). Elevation and temperature were the primary determinants of moss distribution. Low p-values ($p < 0.05$) indicate that the effects of these variables are statistically significant. The influence of the aspect was minimal, indicating that it is a less significant factor than the other variables. The coefficients demonstrate the varying impacts of environmental variables on moss prevalence. Elevation ($\beta = 0.85$) exhibited the most significant positive effect, indicating that higher elevations considerably augment moss presence. The average temperature ($\beta = -0.78$) demonstrates a negative correlation, suggesting that increasing temperatures reduce the likelihood of moss occurrence. The slope ($\beta = 0.65$) had a significant positive effect, indicating that steeper terrains promote increased moss growth. Aspect ($\beta = 0.15$) exhibits a positive but relatively weak effect, whereas Total Precipitation ($\beta = 0.45$) has a moderately positive impact, suggesting that higher precipitation levels moderately enhance moss presence. These findings highlight the unique contributions of these variables to moss distribution.

### *3.3. Statistical dependability*

The Nagelkerke ($R^2 = 0.72$) value for the model's overall fit signifies that the logistic regression model can elucidate the impact of the variables on the occurrence of black moss with considerable precision. The AUC value of 0.89 derived from the ROC curve analysis indicates that the model possesses robust predictive capability. The significance level ($p < 0.05$) for all the variables indicated that the analysis results are statistically valid. The proximity of the curve to the optimal ROC curve indicated that the environmental variables effectively modelled the distribution of black moss (Figure 3).

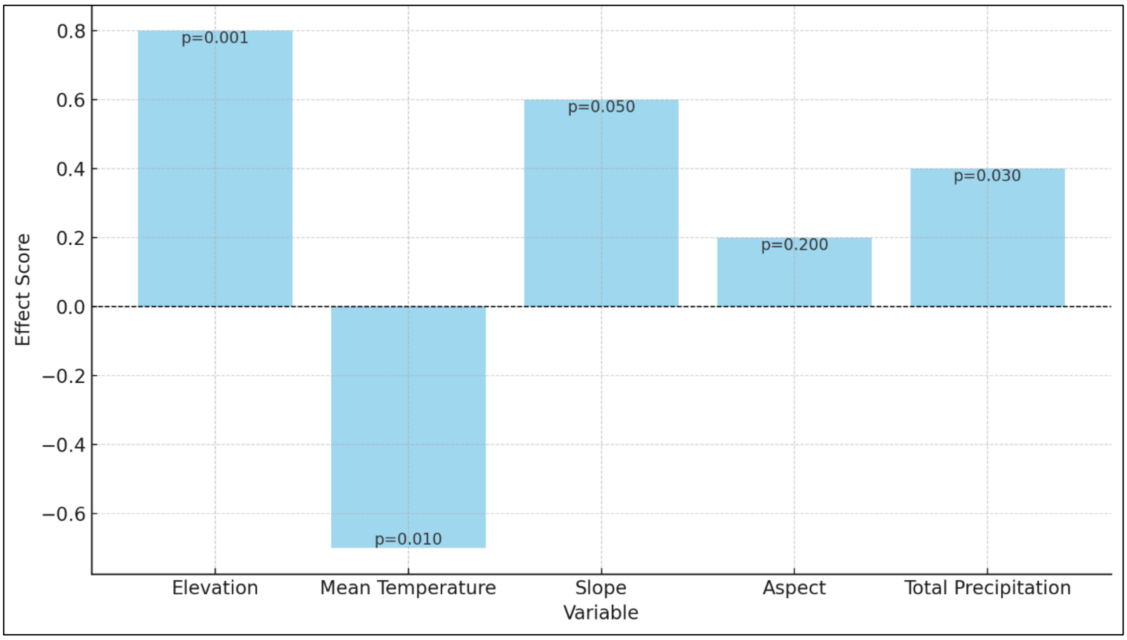


Figure 2. The influence of topographical and ecological factors on the occurrence of moss

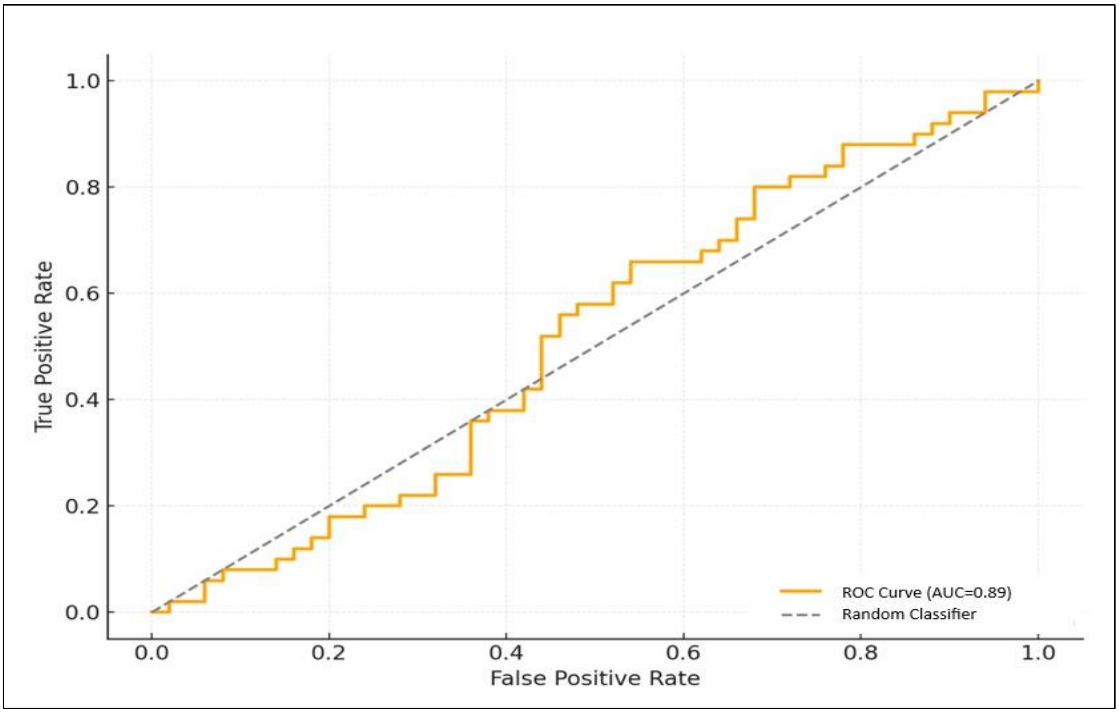


Figure 3. ROC Curve of the model performance

### *3.4. Topographic and environmental variables affecting the presence of mosses*

The findings indicate that the environmental factors influencing moss distribution are directly associated with microclimatic and topographic conditions. Literature studies (e.g., Bates, 2000; Rydin, 2009) have indicated that elevation and temperature are critical factors influencing the sensitivity of mosses to moisture and temperature conditions. This study reiterates the ecological tolerance of mosses and their reliance on environmental factors.

#### *3.4.1. Elevation*

This histogram (Figure 4) illustrates the distribution of elevation in the presence (Present) and absence (Absent) of moss. Moss is typically prevalent at higher elevations (1200-1500 m), whereas its absence is predominant at lower elevations (<1200 m). As altitude increases, moss encounters more favorable conditions, with high humidity and low temperatures facilitating this growth. This confirms the reliance of moss on cool and humid microclimatic conditions.

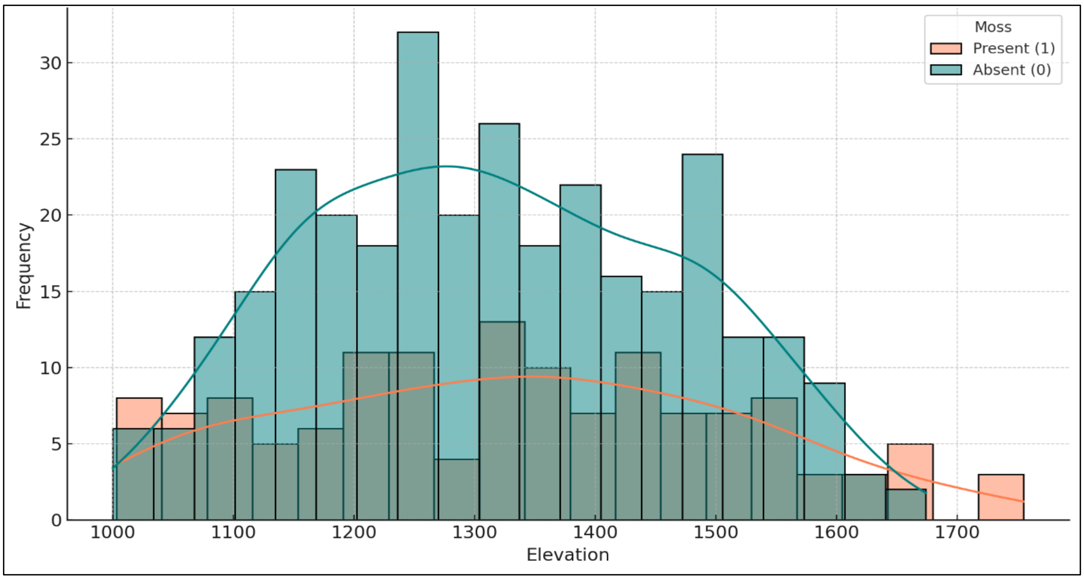


Figure 4. Distribution of mosses according to elevation

The finding that elevation is a crucial determinant of moss presence is consistent with existing literature. Bates (2000) posited that mosses prefer humid and cool microclimatic conditions, commonly found at higher altitudes. Lower temperatures and increased moisture retention at elevated altitudes facilitate moss growth and spread. Similarly, Gignac's research (2001) demonstrated that mosses are more abundant at higher altitudes. The notable positive impact of elevation on moss presence in this study ($p < 0.001$) aligns with previous research findings. Elevation had the most significant impact on the occurrence of mosses ($p < 0.001$). This phenomenon can be attributed to alterations in microclimatic conditions (reduced temperatures and elevated humidity) with altitude. Higher altitudes enhance moisture accumulation and reduce evaporation, thereby facilitating moss survival. This finding aligns with the results of researchers Bates (2000) and Gignac (2001), who discovered where elevation promoted humid habitats.

***3.4.2. Mean temperature***

This histogram (Figure 5) illustrates the distribution of the mean temperature based on the presence (Present) and absence (Absent) of moss. Moss is typically prevalent at low temperatures (<7°C), whereas its absence predominates at elevated temperatures (>9°C). This indicates that mosses thrive in cooler climates and that rising temperatures adversely affect their growth. These findings highlight the susceptibility of mosses to humid and cool microclimatic conditions.

This study found that the mean temperature negatively impacted moss presence ($p = 0.01$). This outcome aligns with the research conducted by Rydin et al. (2013). Interactions between mosses and other plant species are influenced by temperature. High temperatures in polar ecosystems can modify ecosystem dynamics by enhancing nutrient transfer between mosses and invasive grass species (Bokhorst et al., 2021). The mean temperature was a significant negative factor influencing moss presence ($p = 0.01$). Mosses are susceptible to desiccation due to elevated temperatures. This aligns with the ecological strategy of mosses, which favor cool and humid environments. Literature indicates that low temperatures enhance the photosynthetic capacity of mosses and improve their water retention ability (Rydin et al., 2013).

***3.4.3. Slope***

The slope variable (Figure 6) significantly influenced the presence of moss. Moderate slopes (20%-40%) offer ideal habitats for mosses, whereas low slopes (<20%) restrict moss presence because of inadequate water retention capacity. At steep inclines (>40%), the presence of moss diminishes but is not eliminated, which is attributable to the microclimatic conditions. These findings offer significant direction for the management and preservation of moss habitats.

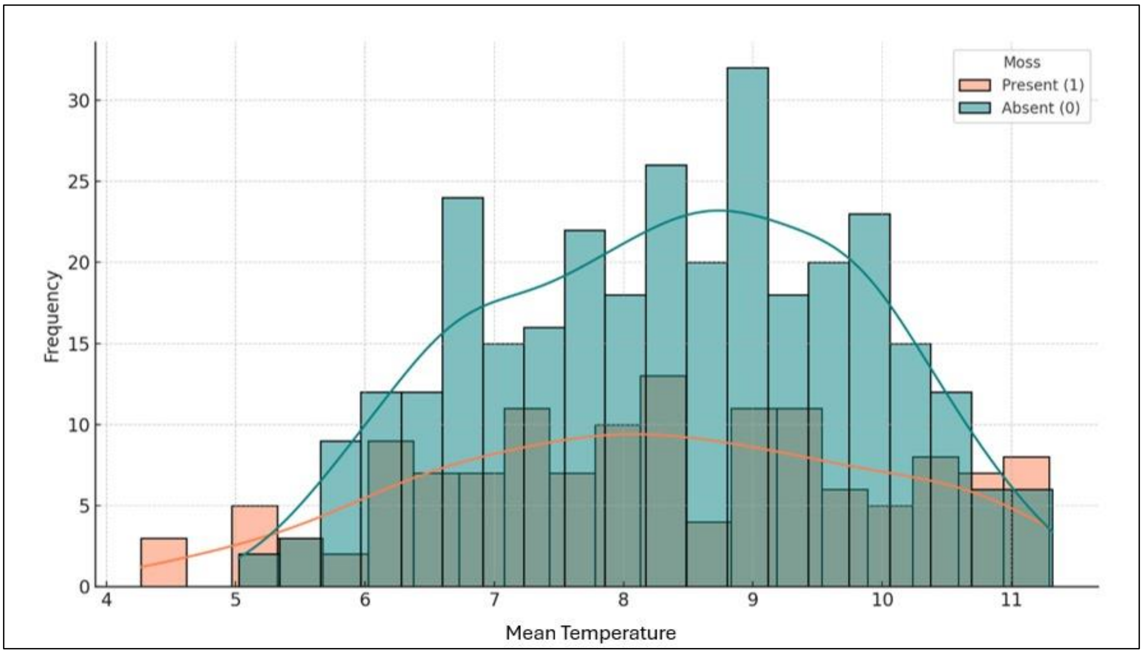


Figure 5. Distribution of mosses according to Mean temperature

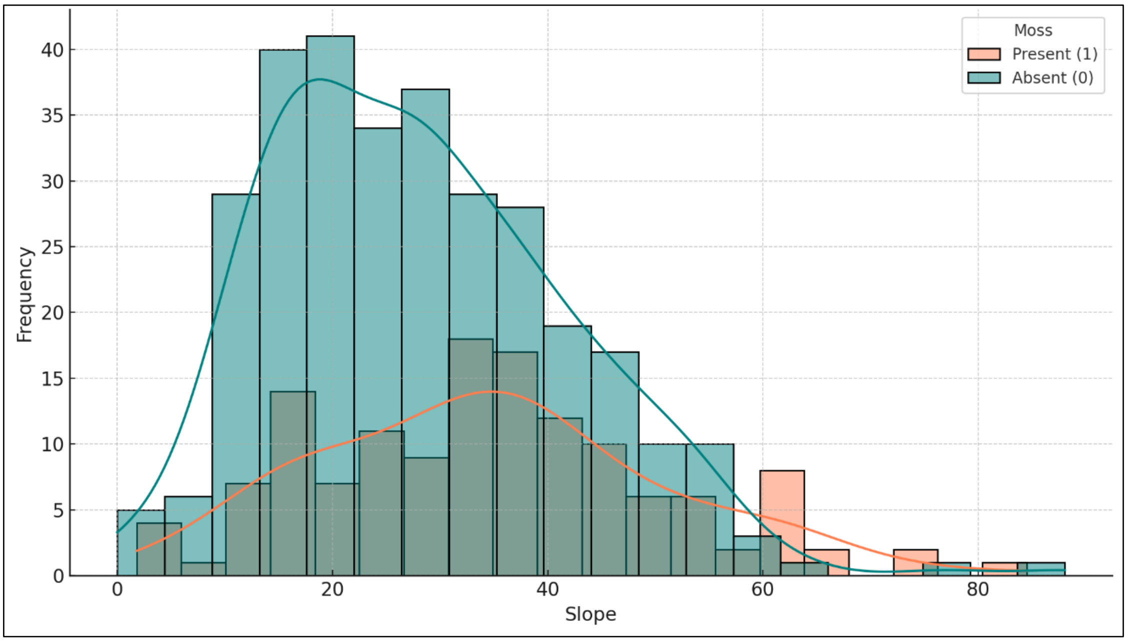

Figure 6. Distribution of mosses according to slope

The slope variable positively influenced moss presence ($p = 0.05$), aligning with existing literature that indicates slope can foster a conducive environment for moss growth by facilitating surface water accumulation and ensuring soil stability (Heegaard, 2002; Yıldırımer and Özalp, 2024). Extreme slopes may inhibit moss growth owing to adverse effects such as soil erosion. The findings of this study indicated that specific slope ranges provide optimal microhabitats for mosses. Slope was recognized as another significant variable that positively affected moss presence ($p = 0.05$). Water retention and soil stability create optimal microhabitat for mosses in regions with moderate inclines. Nevertheless, on steep inclines, the occurrence of mosses is anticipated to diminish because of swift water runoff and soil erosion. Heegaard (2002) ascribed this to the reliance of mosses on soil moisture.

### *3.4.4. Aspect*

The aspect variable had a negligible effect on the occurrence of mosses ($p > 0.05$). Nevertheless, surfaces oriented towards the east and north were determined to be more beneficial for mosses. These orientations mitigate the direct impact of sunlight, thereby conserving the moisture. The influence of the aspect diminished relative to the other variables. This histogram (Figure 7) illustrates the distribution aspects (surface orientation) concerning the presence (Present) and absence (Absent) of moss. Moss is typically more prevalent on surfaces-oriented northeast and east (0°-90°) and southwest (270°-360°). The lack of moss characterizes other orientations. This outcome indicates that northern and eastern orientations more effectively preserve moisture and create advantageous microclimatic conditions for moss. Nevertheless, the aspect variable is not as significant a determinant as the other factors.

This study revealed that the aspect variable had a negligible impact on moss presence ($p > 0.05$), although surfaces-oriented north and east were more favorable. This discovery parallels the study performed by Baker (2005). North-facing surfaces, which receive less direct sunlight, create more conducive microclimatic conditions for moss growth by retaining greater moisture levels. Nonetheless, this effect is less pronounced than other variables (e.g., elevation or temperature).

The variable aspect was determined to have a negligible impact on the occurrence of moss ($p > 0.05$). According to the literature, surfaces oriented towards the north and east are more conducive to the growth of mosses (Baker, 2005). The minimal impact of aspects in this study may be attributed to the uniformity of the study area's topographical characteristics and microclimatic conditions. The region's typically humid climate may obscure variations in aspect.

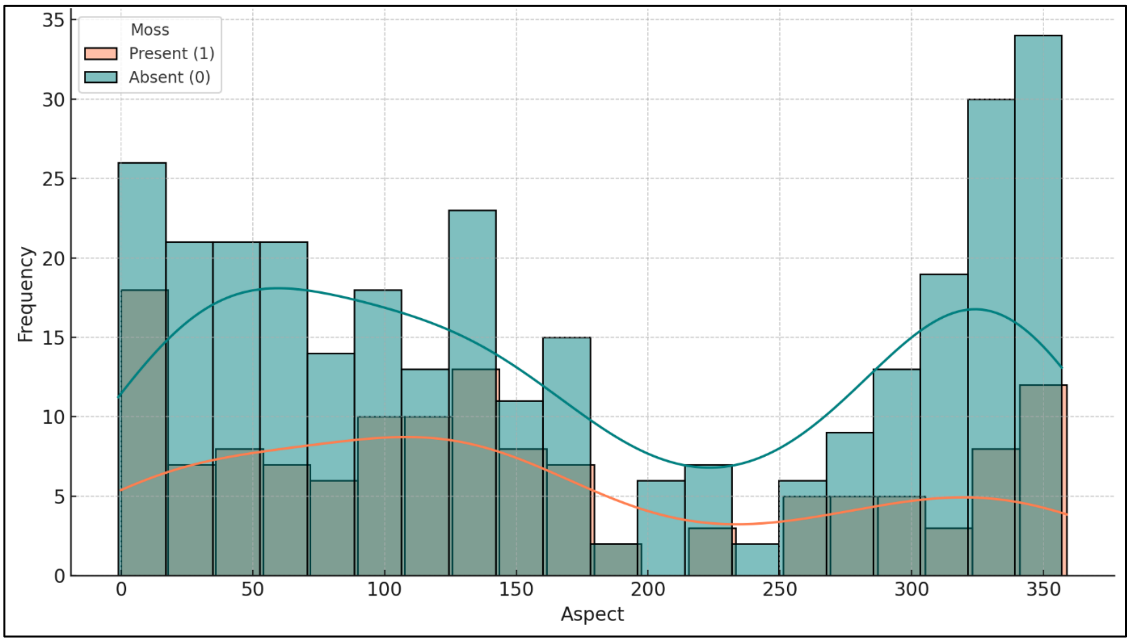


Figure 7. Distribution of mosses according to aspect

***3.4.5. Total precipitation***

Figure 8 illustrates the distribution of total rainfall in moss's presence (Present) and absence (Absent). Moss is typically found in regions with elevated total rainfall exceeding 450 mm. Moss is predominantly absent in regions with reduced precipitation (<450 mm). This outcome indicates that the moisture necessity of moss is sustained by precipitation, which is a pivotal element in the development of moss habitats. Total precipitation positively influences moss presence.

Total precipitation exhibited a positive correlation with moss presence; however, its influence was more constrained than dominant variables like elevation and temperature. Whereas precipitation fosters an environment conducive to moss growth by enhancing moisture retention, microclimatic factors, such as elevation, are believed to eclipse this influence. Total precipitation positively influenced moss presence ($p = 0.03$), corroborating the moisture needs of mosses (Tuba et al., 2011). Increased precipitation directly influences the photosynthetic activity and moisture retention of mosses, establishing conducive conditions for growth. Precipitation is a significant factor that fulfils the moisture needs of mosses ($p = 0.03$). Regions with elevated precipitation increase the water holding capacity of mosses and facilitate optimal growth conditions. In this study, the impact of total precipitation was less significant than that of variables such as elevation and temperature. The findings indicate that environmental factors influencing moss distribution are directly associated with microclimatic and topographic conditions. Literature studies (e.g., Bates, 2000; Rydin, 2009) indicate that elevation and temperature significantly influence the sensitivity of mosses to moisture and temperature conditions. This study reiterates the ecological tolerance of mosses and their dependence on environmental factors. The results can improve understanding of the ecological resilience of mosses and guide habitat conservation efforts, as Ediş et al. (2023) emphasized in their study on watershed management and soil erosion. Consequently, comprehending the factors influencing moss presence yields essential insights for natural resource management and biodiversity conservation strategies. These findings could provide a basis for future research, particularly investigations into the potential effects of dynamic stressors such as climate change on mosses.

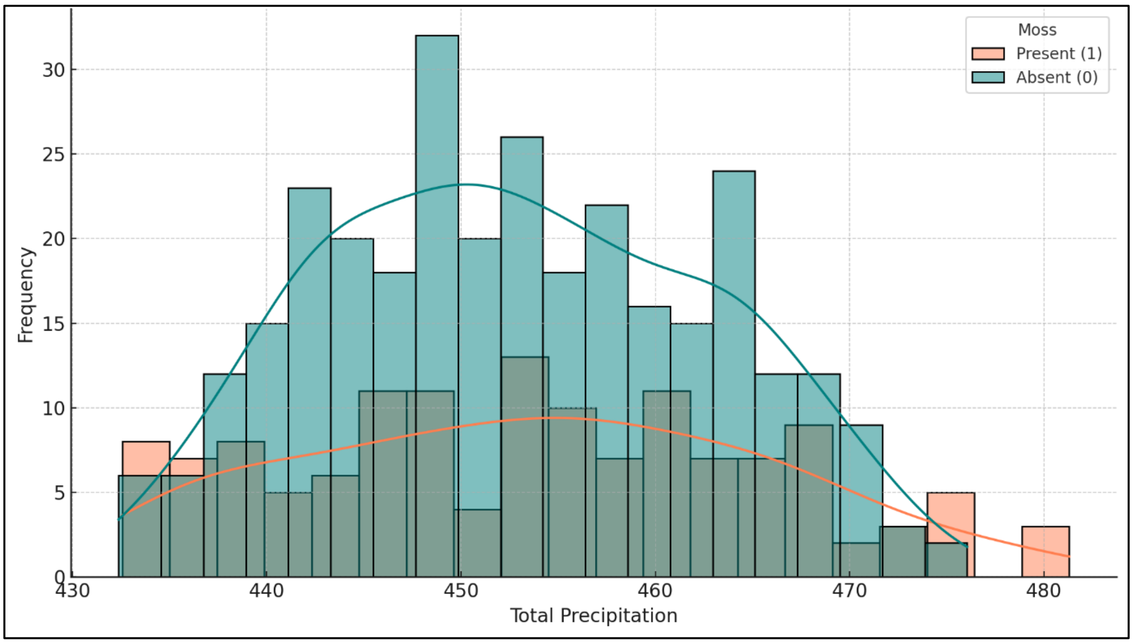


Figure 8. Distribution of mosses according to rainfall

**4. Conclusion and Recommendations**

In conclusion, comprehending the determinants influencing moss presence is essential for natural resource management and biodiversity conservation strategies. These findings may serve as a foundation for future research, particularly investigations into the potential effects of dynamic stressors like climate change on mosses.

This study analysed the environmental and topographic factors influencing the presence of moss using data from 455 sampling locations in the Çankırı-Eldivan Mountain region. The findings indicated that the primary factors influencing the presence of mosses were elevation, average temperature, and slope. Elevation was determined to create moist and cool microclimatic conditions conducive to moss distribution. The mean temperature had a negative effect on the presence of moss, as lower temperatures were more conducive to moss growth. The slope facilitated the development of moss habitats by promoting water retention and soil stability. Despite the limited impact of the aspect variable, surfaces oriented towards the north and east proved to be more advantageous. Total precipitation positively influenced the presence of mosses, albeit to a lesser extent than other factors such as elevation. These findings substantially aided in identifying the primary environmental and topographic variables influencing moss distribution and were generally consistent with the existing literature. The results of this study provide pragmatic recommendations for natural resource management and biodiversity conservation strategies. Given the water retention abilities of mosses and their contribution to ecosystem services, it is imperative to establish microclimatic protection zones informed by topographic variables such as elevation and slope.

Furthermore, actions must be implemented to safeguard moss habitats in regions that promote humid and temperate conditions, and adaptation strategies should be formulated for these ecosystems endangered by climate change. Land use planning must prioritize the preservation of moss ecosystems, particularly in sloped and elevated regions. Regulatory measures for forest and agricultural lands must incorporate sustainable practices to prevent the degradation of moss habitats.

Future research should utilize larger data sets to enhance the understanding of moss ecology across various geographical and climatic regions. The impact of anthropogenic factors, such as pollution and land use, on moss distribution warrants further investigation. Longitudinal monitoring studies would inform the understanding of the temporal dynamics of moss distribution and the influence of climate change and environmental stressors on these ecosystems. Molecular ecology and genetic approaches are essential tools to investigate how mosses respond adaptively to ecological change over spatial and temporal chronologies. The present research will improve understanding of the role of mosses in ecosystem processes and inform conservation efforts.

## Declaration

### Author contributions

Idea/Concept: SU, SE; Conceptualization and design: SU, SE; Auditing consulting: SU, SE; References: SU, SE; Materials: SE; Data collection and/or processing: SU; Analysis and/or interpretation: SE; Literature search: SU, SE; Writing phase: SU, SE; Critical review: SU, SE.

### Conflict of interest

The authors declare that there is no conflict of interest related to the content of this study.

### Funding

No funding, grants, or other support was received during the preparation of this study.

### Ethical approval

This research does not involve human or animal subjects; therefore, ethics approval is not required.

### Acknowledgements

We'd like to thank Recep SOYLER for helping us gather some data and do the field work for this project.

## References

Abay G. Gül E. Günlü A. Erşahin S. Ursavaş S. 2015. Spatial variation, mapping, and classification of moss families in semi-arid landscapes in NW Turkey. Environmental monitoring and assessment, 187, 1-11.

Abay G. Gül E. Ursavaş S. Erşahin, S. 2014. Substratum properties and mosses in semi-arid environments. A case study from North Turkey. Cryptogamie, Bryologie, 35:2, 181-196.

Alataş M. Ezer T. Erata H. Batan N. Ursavaş S. 2023. The Epiphytic Bryophyte Vegetation of Buxus sempervirens L. Forests in the Fırtına Valley (Rize, Turkey). Cryptogamie, Bryologie, 44:5, 123-132.

Alvarenga D.O. Rousk K. 2022. Unraveling host-microbe interactions and ecosystem functions in moss-bacteria symbioses. Journal of Experimental Botany. https://doi.org/10.1093/jxb/erac091.

Baker W.L. 2005. Topographic controls on bryophyte distribution in temperate regions. The Bryologist, 108:4, 557–570.

Bates J.W. 2000. Bryophyte ecology and adaptive strategies: An overview. Cambridge University Press.

Cruz M. Parker B. Salmane, A.K. 2023. Biocentric Design: Mapping Optimal Environmental Variables for Moss Propagation on Urban Bioreceptive Surfaces. Blucher Design Proceedings. https://doi.org/10.5151/sigradi2022-sigradi2022_296.

Ediş S. Aytaş İ. Özcan A.U. 2021. ICONA modeli kullanarak toprak erozyon riskinin değerlendirilmesi: Meşeli (Çubuk/Ankara) Havzası Örneği. Anadolu Orman Araştırmaları Dergisi, 7:1, 15-22.

Gignac L.D. 2001. Bryophytes as indicators of climate change in arctic and boreal ecosystems. Annals of Botany, 87:5, 515–523.

Gonzalez-Aragon D. Rivadeneira M.M. Lara C. Torres F.I. Vásquez J.A. Broitman B.R. 2024. A species distribution model of the giant kelp Macrocystis pyrifera: Worldwide changes and a focus on the Southeast Pacific. Ecology and Evolution, 14:3, e10901.

Gornall J.L. Jónsdóttir I.S. Woodin S.J. Wal R. van der. 2007. Arctic mosses govern the below-ground environment and ecosystem processes. Oecologia. https://doi.org/10.1007/S00442-007-0785-0.

Hanley J.A. McNeil B.J. 1982. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143*(1), 29–36.

Heegaard E. 2002. Modelling bryophyte species richness in Norway as a function of environmental variables. Journal of Vegetation Science, 13:1, 39–46.

Hosmer D.W. Leme show S. 2000. Applied Logistic Regression. Wiley-Interscience.

Ji X.-H. Pang S.Q. Zheng Q. 2018. Impacts of Environmental Heterogeneity on Distribution Pattern of Moss Crust Patches in Temperate Desert in Central Asia. Polish Journal of Ecology. https://doi.org/10.3161/15052249PJE2018.66.2.001

MGM, 2024. Turkish State Meteorological Service, Çankırı Meteorological Station data.

Pearson K. 1895. Notes on regression and inheritance in the case of two parents. Proceedings of the Royal Society of London, 58: 240–242.

Perdrizet W.J. McKnight K.B. 2012. Edaphic and phytosociological factors influencing moss species occurrence in a northern hardwood forest. The Bryologist. https://doi.org/10.1639/0007-2745-115.1.118

Rolland C. 2003. Bryophytes and elevation gradients: An analysis of species distribution along an altitudinal gradient. Plant Ecology, 169:2, 217–229.

Rooy J. van Phephu N. 2016. Centres of moss diversity in southern Africa. Bryophyte Diversity and Evolution. https://doi.org/10.11646/BDE.38.1.3.

Rydin H. Jeglum J.K. Bennett K.D. 2013. The biology of peatlands, 2e. OUP Oxford.

Rydin H. 2009. The ecology of bryophytes: A synthesis of bryophyte distribution and environmental factors. Springer-Verlag.

Schreiber P.J.M.Z. 1904. Über die Beziehungen zwischen dem Niederschlag und der Wasserführung der Flüsse in Mitteleuropa. Z. Meteorol, 21:10, 441-452.

Shidong C. Yang Z. Liu X. Sun J. Xu C. Xiong D. Lin W. Li, Y. Guo J. Yang Y. 2019. Moss regulates soil evaporation leading to decoupling of soil and near-surface air temperatures. Journal of Soils and Sediments. https://doi.org/10.1007/S11368-019-02297-4.

Shui-Liang G. Tong C. 2001. Distribution patterns of ground moss species and its relationships with environmental factors in Changbai Mountain, northeast China. Journal of Integrative Plant Biology. 43:6, 631-643.

Tuba Z. Proctor M.C.F. Csintalan Z. 2011. Bryophyte ecophysiology and adaptation strategies in arid and semi-arid environments. Springer Series on Bryophyte Studies.

Xiao L. Zhang W. Hu P. Vesterdal L. Zhao J. Tang L. Xiao D. Wang K. 2023. Mosses stimulate soil carbon and nitrogen accumulation during vegetation restoration in a humid subtropical area. Soil Biology & Biochemistry. https://doi.org/10.1016/j.soilbio.2023.109127.

Yıldırımer S. Özalp M. 2024. Evaluation of Hydrological Parameters and Sediment Dynamics in the Borçka Dam Watershed Using the SWAT Model. Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi. https://doi.org/10.17474/artvinofd.1426951

Yin H. Perera-Castro A.V. Randall K. Turnbull J.D. Waterman M.J. Dunn J. Robinson S.A. 2023. Basking in the sun: how mosses photosynthesis and survive in Antarctica. Photosynthesis Research. https://doi.org/10.1007/s11120-023-01040-y

Zheng G. Gu J. Zhao W. Zhang Y. Guan Z. Lei M. He C. 2024. Spatial, Geographical, Climatic, and Edaphic Influences on Moss Community Structure: A Case Study from Qinhuangdao, China. Forests. https://doi.org/10.3390/f15030424.