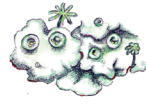




Moss



Liverwort



Hornwort

<http://bryology.karatekin.edu.tr/>

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## The Urban Moss Flora of the Çankırı City (NW, Turkey)

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### Abstract

The mosses found in the urban area of Çankırı city was investigated at five zones depending on the human activities. Two hundreds and thirty five specimens were randomly collected in sampling locations within the zones. As a result of the identification, 66 taxa were recorded. The results were compared with the explored urban floras of the other countries. Data on life forms, frequency of occurrence, presence of sporophytes, habitats and substrata preferences of the mosses were discussed. Detailed topographical features including slope, aspect and altitude analysis of the study area were illustrated and taxa occurrence was evaluated based on these properties. Chi-square analysis revealed that 45 moss species of 235 were correlated with the categorical variables at 0.05 significance level. Moss taxa occurrence within the urban area was mainly correlated with life forms and gametophyte structures, respectively.

**Key Words:** Flora, Urban mosses, Human impact, Categorical variables, Turkey

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## 1. Introduction

Urban environments as known complex ecological systems are characterized by relatively dry climate conditions, presence of pollutants, some microhabitats (Pokorny et al., 2006), and also a high degree of habitat heterogeneity (Fojcik and Stebel, 1999). These landscapes are generally affected by human activities (Barrico et al., 2012) and human actions are important when studying urban flora or ecology (Đurđić et al., 2011).

Urban areas present some specific microhabitats considering the small structured plants like bryophytes which are widely adjusted to such environment. Thus, bryophyte diversity of urban sites constitute an important part of the city vegetation (Sabovljević and Sabovljević, 2009; Sabovljević and Grdović, 2009). These simple organisms service as pioneering species at the initial colonization phase of urban environments and help to improve the conditions for vascular plants (Jim and Chen, 2011). Urban mosses are also widely used as biomonitors to determine the heavy metals due to the air pollution in cities. They have ability to accumulate pollutants in their structures (Skudnik et al., 2013). When considered together with all of them, urban moss diversity gives much information on the environmental conditions and biological peculiarities of some moss taxa (Pokorny et al., 2006).

Many bryophyte studies were carried out in the urban areas of different countries. Some of those are; the city of Enna (Lo Giudice et al., 1997) and Trento (Pokorny et al., 2006) in Italy; the city of Mexico (Delgadillo and Cárdenas, 2000) in Mexico, the city of Belgrad (Grdović and Stevanović, 2006; Sabovljević and Grdović, 2009) in Serbia, the Campus of

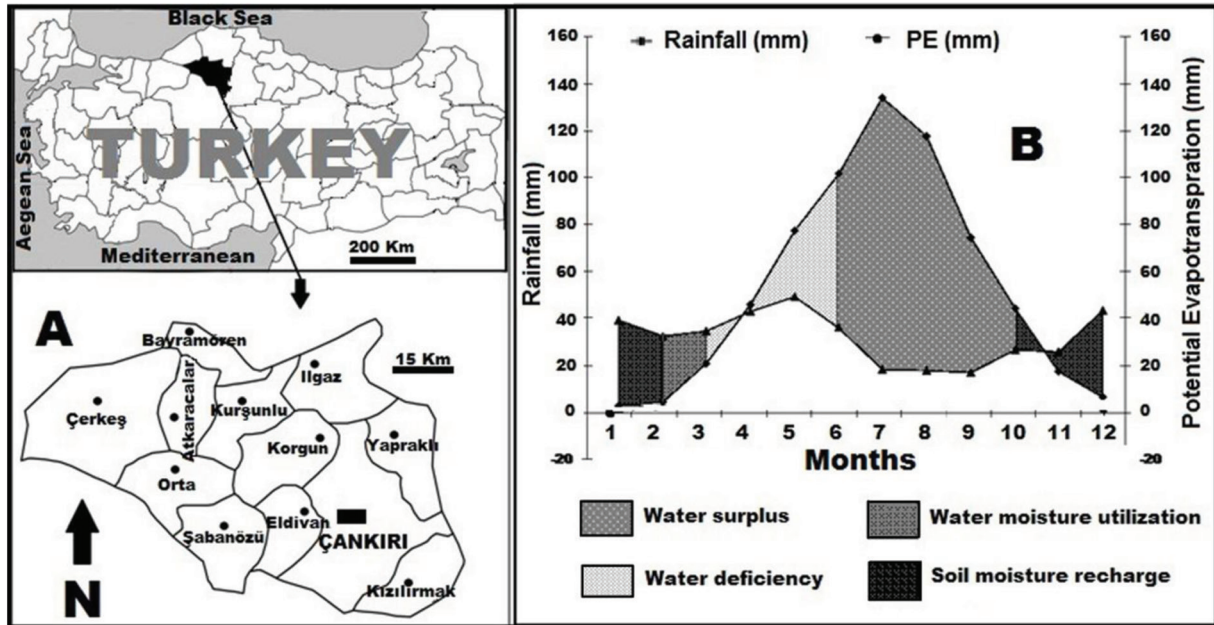
the University of Bremen (Isermann, 2007) and the city of Cologne (Sabovljević and Sabovljević, 2009) in Germany, the towns of Toro and Benavente (2008) in Spain, the city of Monchegorsk (Drugova, 2010) in NW Russia, the city of Katowice (Fojcik and Stebel, 2006) and the town of Wroclaw (Fudali, 2012) in Poland, the city of Ljubljana (Skudnik et al., 2013) in Slovenia.

In Turkey, studies of urban bryophytes have continued as scarcely (Kirmaci and Ağcagil, 2009) and data about their biology and ecology is limited. The survey aimed to determine the mosses within the urban area of Çankırı center, understand the effects of environmental factors on the moss occurrence in the urban conditions, and compare the moss diversity within the urban areas of different countries

## 2. Study Area and Methods

Çankırı is situated in the northwest of the Central Anatolia, and between Kızılırmak and West Black Sea main basins and located in semi-arid region. The geographic coordinates of the study area is 40° 30' 41'' N and 32° 30' 34'' E). The average elevation above sea level of the city is 750 m (Environmental Status Report, 2014; Fig.1A).

Based on 54 years of climatic data (1960-2013), the annual average temperature is 11.2°C; the average of the lowest monthly temperatures is -4.2°C in January while the highest recorded is 30.9°C in July and August; the mean annual relative humidity is 66.0%; the annual average precipitation is 405.6 mm, with maximum in May (53.9 mm), and with minimum in September (16.3 mm) (Directorate General of Meteorology, 2013; Fig. 1B).



Figures 1A-B. Map of the study area (A) and climate diagram (B) of Çankırı

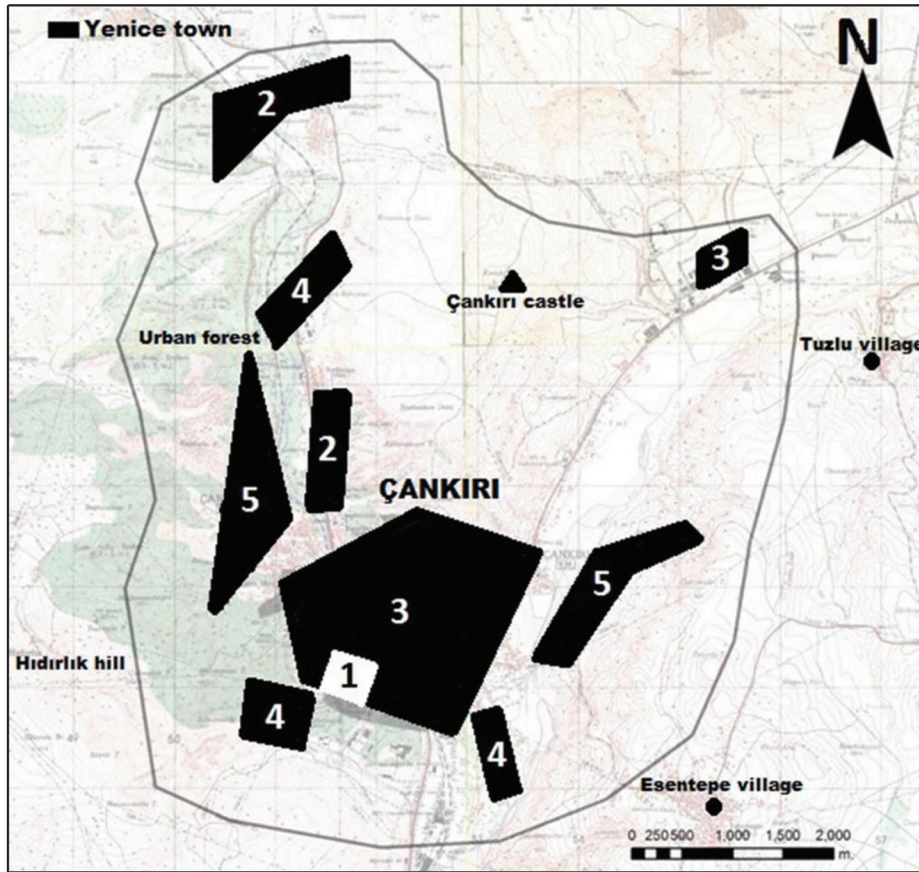
A moss collection was made in the urban area of Çankırı province during 2013 and 2014. In total 235 moss taxa were collected from different substrates within the boundary of the municipality. Sampling procedures were based on representative studies conducted in different countries (Lo Giudice et al., 1997; Pokorny et al., 2006; Sabovljević and Sabovljević, 2009). The city was divided into five zones which are old city (1); modern city (2); protected areas (3); river sides (4); and uncultivated areas (5) according to the variation of the human use (Fig. 2). Old city includes wood and brick infill used in places, where the two-storey house, the traffic is restricted, and historical sites. Modern city are the residential areas, workplaces, where the traffic is not limited and trees are quite common along the streets, large and sunny asphalted streets, and public parks. Protected areas correspond to the urban forest, promenade, cemeteries, government agencies and school yards. Riversides are around the stream beds. Uncultivated areas comprise hills near the urban area and where human activities are scattered.

A random sampling was made in various habitats within the zones. Mosses were collected from natural and man-made habitats. The elevation, geographical coordinates, substrates, slopes, and life forms about the mosses were recorded.

The moss samples were identified using the related literatures (Greven, 2003; Smith, 2004; Heyn and Herrnstadt, 2004). Moss taxa order and nomenclature were those of Hill et al. (2006). Life forms types of the taxa were those of Hill et al. (2007).

Slope-aspect analysis and diorama of the study area were mapped using ArcGIS 10.0 packaged software. Slope classes according to Forstliche Standort 1966 saufnahme were used in the creations of slope analysis and mapping (Çepel, 1995). The values were given as percentage for better understanding of slope maps. Aspect analysis was conducted considering flat areas with main and intermediate direction and nine different aspect groups were obtained.





**Figure 2.** Study area showing the sampling zones (1-5) based on differential human use

**3. Data Analysis**

Statistical analysis was performed using chi-square ( $\chi^2$ ) test. Categorical variables used in calculations were locality, aspect, slope group, zone, sporophyte, and gametophyte. Relationships between the moss occurrence and the distributions of these variables were analyzed using crosstabs. Significance levels correlated with crosstabs and calculation of the statistics

were performed using SPSS 20.0 software for Windows (SPSS 20.0 Inc., 2012).

**4. Results and Discussion**

**4.1. Moss flora**

A total of 66 moss taxa belonging to 27 genera and 10 families, collected from 235 taxa, were found in the urban area. A survey of moss flora in the study area is as follows:

***ENCALYPTACEAE***

1. *Encalypta rhaptocarpa* Schwägr – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tuft.

2. *Encalypta vulgaris* Hedw. – Protected areas, north-east aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58", and life form: Tf.

***FUNARIACEAE***

3. *Funaria hygrometrica* Hedw. – Old city, east aspect, on soil, 792 m, E 33° 36' 38.40" - N 40° 35' 38.69"; on sidewalk, 796 m, E 33° 36' 37.75" - N 40° 35' 37.29"; northeast aspect, on soil, 718 m, E 33° 37' 01.63" - N 40° 35' 38.76" – Modern city, east



aspect, on soil, 725 m, E 33° 37' 14.31" - N 40° 35' 34.28"; northeast aspect, on concrete, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09"; on northeast aspect, on rock, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09"; Protected areas, southeast aspect, on sidewalk, 720 m, E 33° 37' 32.26" - N 40° 35' 42.87"; northeast aspect, on sidewalk, 711 m, E 33° 37' 36.69" - N 40° 35' 57.70"; southeast aspect, on wall, 740 m, E 33° 37' 21.75" - N 40° 36' 10.27", and life form: Tf.

#### **GRIMMIACEAE**

4. *Grimmia anodon* Bruch & Schimp. – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Cu.

5. *Grimmia donniana* Sm. – Uncultivated areas, north aspect, on rock, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Cu.

6. *Grimmia funalis* (Schwägr.) Bruch & Schimp. – Riversides, northeast aspect, on rock, 812 m, E 33° 36' 03.45" - N 40° 35' 36.96", and life form: Cu.

7. *Grimmia orbicularis* Bruch ex Wilson – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Cu.

8. *Grimmia pulvinata* (Hedw.) Sm. – Protected areas, northeast aspect, on rock, 810 m, E 33° 35' 50.74" - N 40° 38' 34.84"; north aspect, on wall, 740 m, E 33° 36' 49.23" - N 40° 35' 46.44" – Riversides, plane, on rock, 795 m, E 33° 36' 09.00" - N 40° 35' 39.13" – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33"; southeast aspect, on rock, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.

9. *Grimmia trichophylla* Grev. – Old city, east aspect, on concrete, 755 m, E 33° 36' 24.64" - N 40° 36' 00.84" – Protected areas, east aspect, on rock, 810 m, E 33° 35' 48.74" - N 40° 38' 35.11", northeast aspect, on rock, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58"; north aspect, on concrete, 776 m, E 33° 36' 16.23" - N 40° 36' 15.81"; northwest aspect, on rock, 778 m, E 33° 36' 31.99" - N 40° 38' 00.80" – Riversides, plane, on rock, 815 m, E 33° 36' 02.01" - N 40° 35' 37.16" – Uncultivated areas, north aspect, on rock, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; southeast aspect, on rock, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.

10. *Schistidium apocarpum* Hedw. (Bruch & Schimp.) – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tuft.

#### **DITRICHACEAE**

11. *Ceratodon purpureus* (Hedw.) Brid. – Modern city, north aspect, on soil, 805 m, E 33° 36' 14.43" - N 40° 35' 37.19"; east aspect, on ladder, 755 m, E 33° 36' 15.33" - N 40° 36' 19.93" – Protected areas, northeast aspect, on soil, 773 m, E 33° 35' 53.35" - N 40° 38' 45.34", plane, on soil, 888 m, E 33° 36' 59.85" - N 40° 36' 35.65"; north aspect, on concrete, 776 m, E 33° 36' 16.23" - N 40° 36' 15.81"; north aspect, on ladder, 776 m, E 33° 36' 16.23" - N 40° 36' 15.81"; west aspect, on soil, 763 m, E 33° 36' 31.63" - N 40° 37' 03.14"; plane, on rock, 763 m, E 33° 36' 27.60" - N 40° 37' 51.68" – Riversides, north aspect, on soil, 804 m, E 33° 36' 10.09" - N 40° 35' 36.85" – Uncultivated areas, northeast aspect, on rock, 747 m, E 33° 36' 25.98" - N 40° 35' 57.98"; northeast aspect, on soil, 809 m, E 33° 35' 49.04" - N 40° 36' 11.25"; northwest aspect, on rock, 747 m, E 33° 38' 39.84" - N 40° 36' 24.57"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on soil, 793 m., E 33° 36' 10.65" -

N 40° 35' 37.60"; north aspect, on trees, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; southeast aspect, on soil, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Tf.

12. *Ditrichum flexicaule* (Schwägr.) Hampe – Uncultivated areas, north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tuft.

### **POTTIACEAE**

13. *Pleurochaete squarrosa* (Brid.) Lindb. – Protected areas, east aspect, on soil, 783 m, E 33° 35' 52.29" - N 40° 38' 45.93"; northeast aspect, on soil, 772 m, E 33° 35' 54.43" - N 40° 38' 37.42"; northeast aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58" – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

14. *Tortella inclinata* (R. Hedw.) Limpr. var. *densa* (Lorentz & Molendo) Limpr. – Protected areas, east aspect, on rock, 791 m, E 33° 35' 53.21" - N 40° 38' 34.47"; northeast aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58", and life form: Tuft.

15. *Tortella tortuosa* (Hedw.) Limpr. – Protected areas, northeast aspect, on soil, 791 m, E 33° 35' 51.55" - N 40° 38' 34.74", and life form: Tuft.

16. *Weissia condensa* (Voit) Lindb. – Uncultivated areas, north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

17. *Weissia controversa* Hedw. – Protected areas, south aspect, on sidewalk, 741 m, E 33° 39' 19.71" - N 40° 38' 00.99", and life form: Tf.

18. *Barbula convoluta* Hedw. – Protected areas, west aspect, on wall, 779 m, E 33° 36' 28.50" - N 40° 38' 57.96", and life form: Tf.

19. *Barbula unguiculata* Hedw. – Modern city, plane, on wall, 737 m, E 33° 36' 29.67" - N 40° 36' 44.21" – Protected areas, southeast aspect, on soil, 781 m, E 33° 35' 54.02" - N 40° 38' 44.85"; northeast aspect, on soil, 732 m, E 33° 37' 00.22" - N 40° 35' 38.11"; northeast aspect, on log, 754 m, E 33° 36' 24.76" - N 40° 36' 18.06", and life form: Tf.

20. *Crossidium crassinerve* (De Not.) Jur. – Riversides, plane, on soil, 746 m, E 33° 36' 09.76" - N 40° 37' 40.78" – Uncultivated areas, north aspect, on soil, 793 m., E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Tf.

21. *Crossidium squamiferum* (Viv.) Jur. var. *pottioideum* (De Not.) Mönk. – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33"; north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

22. *Didymodon tophaceus* (Brid.) Lisa – Protected areas, east aspect, on sidewalk, 714 m, E 33° 37' 22.87" - N 40° 35' 26.58", and life form: Tf.

23. *Protobryum bryoides* (Dicks.) J.Guerra & M.J.Cano – Protected areas, northeast aspect, on wall, 750 m., E 33° 36' 20.84" - N 40° 36' 17.96", and life form: Tf.

24. *Pseudocrossidium revolutum* (Brid.) R.H.Zander – Uncultivated areas, north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

25. *Pterygoneurum ovatum* (Hedw.) Dixon – Modern city, northeast aspect, on mortar, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09" – Protected areas, northeast aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58" - Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Ts.



26. *Syntrichia caninervis* Mitt. var. *caninervis* – Protected areas, east aspect, on rock, 847 m, E 33° 37' 27.15" - N 40° 36' 32.94"; south aspect, on rock, 732 m, E 33° 37' 58.83" - N 40° 36' 25.76", and life form: Tf.

27. *Syntrichia caninervis* Mitt. var. *gypsophila* (J.J.Amann ex G.Roth) Ochyra – Protected areas, east aspect, on rock, 847 m, E 33° 37' 27.06" - N 40° 36' 32.94"; west aspect, on soil, 777 m., E 33° 36' 31.33" - N 40° 37' 12.22" – Uncultivated areas, northwest aspect, on soil, 747 m., E 33° 38' 10.06" - N 40° 35' 59.08"; northeast aspect, on rock, 740 m, E 33° 38' 56.68" - N 40° 36' 28.59", and life form: Tf.

28. *Syntrichia latifolia* (Bruch ex Hartm.) Huebener – Protected areas, southeast aspect, on concrete, 765 m, E 33° 36' 28.69" - N 40° 38' 54.75", and life form: Tf.

29. *Syntrichia montana* Nees – Protected areas, northeast aspect, on concrete, 750 m, E 33° 36' 20.29" - N 40° 36' 18.32", and life form: Tuft.

30. *Syntrichia papillosissima* (Copp.) Loeske – Protected areas, plane, on soil, tuft, 811 m, E 33° 35' 49.85" - N 40° 38' 34.95", and life form: Tuft.

31. *Syntrichia ruralis* (Hedw.) F.Weber & D.Mohr var. *ruralis* – Protected areas, southeast aspect, on soil, 781 m, E 33° 35' 53.60" - N 40° 38' 43.96"; east aspect, on soil, 772 m, E 33° 35' 52.57" - N 40° 38' 49.11" – plane, on soil, 858 m, E 33° 36' 57.78" - N 40° 36' 36.60"; east aspect, on soil, 775 m., E 33° 37' 25.48" - N 40° 36' 18.65"; north aspect, on ladder, 776 m., E 33° 36' 16.23" - N 40° 36' 15.81"; southeast aspect, on wall, 707 m, E 33° 37' 42.95" - N 40° 35' 17.52" - Riversides, north aspect, on soil, 804 m, E 33° 36' 07.16" - N 40° 35' 37.91"; east aspect, on soil, 812 m, E 33° 36' 04.23" - N 40° 35' 38.22"; northwest aspect, on soil, 747 m, E 33° 38' 10.06" - N 40° 35' 59.08"; plane, on rock, 749 m, E 33° 36' 09.85" - N 40° 37' 41.88" – Uncultivated areas, northwest aspect, on soil, 747 m, E 33° 38' 10.06" - N 40° 35' 59.08"; north aspect, on rock, 809 m, E 33° 38' 56.43" - N 40° 36' 28.36"; east aspect, on soil, 767 m, E 33° 36' 02.67" - N 40° 37' 24.57"; north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33"; southeast aspect, on soil, 788 m., E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Tf.

32. *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr var. *ruraliformis* (Besch.) Delogne – Protected areas, east aspect, on soil, 847 m, E 33° 37' 27.15" N 40° 36' 32.94" – Riversides, north aspect, on rock, 801 m, E 33° 36' 10.26" - N 40° 35' 37.50", and life form: Tf.

33. *Tortula brevissima* Schiffn. – Protected areas, southeast aspect, on wall, 770 m, E 33° 36' 16.86" - N 40° 36' 14.96"; west aspect, on wall, 779 m, E 33° 36' 28.50" - N 40° 38' 57.96" – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

34. *Tortula canescens* Mont. – Modern city, northeast aspect, on wall, 718 m, E 33° 37' 14.37" - N 40° 35' 32.20" – Protected areas, north aspect, on rock, 756 m, E 33° 36' 24.50" - N 40° 37' 52.15"; plane, on rock, 780 m, E 33° 36' 31.44" - N 40° 38' 01.00" – Uncultivated areas, east aspect, on rock, 778 m, E 33° 36' 20.35" - N 40° 36' 00.96", and life form: Tf.

35. *Tortula inermis* (Brid.) Mont. – Modern city, plane, on concrete, 775 m, E 33° 36' 33.39" - N 40° 36' 59.56" - Protected areas, on rock, 810 m, E 33° 35' 48.74" - N 40° 38' 35.11"; east aspect, on concrete, 816 m, E 33° 37' 25.77" N 40° 36' 26.75"; plane, on wall, 730 m, E 33° 36' 49.55" - N 40° 36' 06.84"; southeast aspect, on wall, 750 m., E 33° 37' 27.85" - N 40° 36' 11.95"; east aspect, on wall, 753 m, E 33° 36' 27.03" - N 40° 35' 51.65"; northeast aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58" - Uncultivated areas, southeast aspect, on concrete, 788 m, E 33° 35' 54.32" - N

40° 38' 44.17"; southeast aspect, on soil, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Tf.

36. *Tortula lanceola* R.H.Zander – Uncultivated areas, north aspect, on soil, 810 m., E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

37. *Tortula modica* R.H.Zander – Uncultivated areas, on soil, 793 m, E 33° 36' 10.65" - N 40° 38' 37.49", and life form: Tf.

38. *Tortula muralis* Hedw. – Old city, north aspect, on sidewalk, 740 m, E 33° 36' 32.03" - N 40° 35' 58.70" – Modern city, west aspect, on concrete, 758 m, E 33° 36' 33.69" - N 40° 36' 55.73"; northeast aspect, on mortar, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09" – Protected areas, northeast aspect, on sidewalk, 730 m, E 33° 37' 23.76" - N 40° 35' 26.38"; east aspect, on concrete, 735 m, E 33° 36' 24.90" - N 40° 35' 51.99"; southeast aspect, on concrete, 786 m, E 33° 36' 28.22" - N 40° 38' 54.79" - Riversides, plane, on rock, 749 m, E 33° 36' 09.85" - N 40° 37' 41.88"; Uncultivated areas, east aspect, on wall, 765 m, E 33° 36' 03.40" - N 40° 37' 24.69"; north aspect, on rock, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; southeast aspect, on concrete, 788 m., E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Tf.

39. *Tortula subulata* Hedw. – Old city, plane, on sidewalk, 789 m, E 33° 36' 32.23" - N 40° 35' 38.69"; southeast aspect, on wall, 761 m, E 33° 36' 21.28" - N 40° 36' 00.60" – Modern city, west aspect, on wall, 785 m, E 33° 36' 33.40" - N 40° 36' 56.39" – Protected areas, northeast aspect, on wall, 730 m, E 33° 36' 46.08" - N 40° 36' 04.20"; west aspect, on concrete, 765 m, E 33° 36' 28.63" - N 40° 37' 00.82"; west aspect, on wall, 774 m, E 33° 36' 30.59" - N 40° 37' 14.89" – Riversides, plane, on wall, 708 m, E 33° 37' 44.48" - N 40° 35' 11.96" – Uncultivated areas, northeast aspect, on wall, 745 m, E 33° 36' 28.27" - N 40° 36' 01.44"; northeast aspect, on wall, 745 m, E 33° 36' 11.27" - N 40° 36' 37.20"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Tuft.

40. *Tortula vahliana* (Schultz) Mont. – Modern city, plane, on concrete, 727 m., E 33° 37' 21.38" - N 40° 35' 49.65" – Protected areas, south aspect, on wall, 746 m, E 33° 37' 26.22" - N 40° 36' 10.76", and life form: Tf.

#### **ORTHOTRICHACEAE**

41. *Orthotrichum anomalum* Hedw. – Uncultivated areas, southeast aspect, on rock, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.

42. *Orthotrichum cupulatum* Hoffm. ex Brid. – Uncultivated areas, southeast aspect, on rock, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", life form: Cu.

43. *Orthotrichum urnigerum* Myrin – Protected areas, northeast aspect, on rock, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58", life form: Cu.

44. *Orthotrichum diaphanum* Schrad. ex Brid. – Protected areas, north aspect, on tree (*Morus* sp.), 715 m, E 33° 37' 18.08" - N 40° 35' 28.48"; west aspect, on tree (*Acer* sp.), 779 m, E 33° 36' 28.50" - N 40° 38' 57.96" – Uncultivated areas, southeast aspect, on concrete, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17"; southeast aspect, on tree (*Thuja* sp.), 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.

45. *Orthotrichum rupestre* Schleich. ex Schwägr. – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Cu.

46. *Orthotrichum affine* Schrad. ex Brid. – Uncultivated areas, southeast aspect, on tree (*Aesculus hippocastanum*), 788 m, E 33° 35' 54.32" - N 40° 38' 44.17"; southeast aspect, on tree (*Malus* sp.), 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.



47. *Orthotrichum lyellii* Hook. & Taylor – Uncultivated areas, southeast aspect, on tree (*Malus* sp.), Cu, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Cu.

#### **BRYACEAE**

48. *Bryum argenteum* Hedw. – Old city, southeast aspect, on sidewalk, 792 m, E 33° 36' 32.58" - N 40° 35' 39.89"; north aspect, on wall, 713 m, E 33° 37' 14.35" - N 40° 35' 29.77" – Modern city, south aspect, on concrete, 720 m, E 33° 36' 56.63" - N 40° 36' 04.34"; northeast aspect, on concrete, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09"; northeast aspect, on rock, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09" – Protected areas, southeast aspect, on wall, 718 m, E 33° 37' 30.64" - N 40° 35' 42.65"; east aspect, on sidewalk, 773 m, E 33° 36' 15.73" - N 40° 36' 12.79"; east aspect, on soil, 773 m, E 33° 36' 15.73" - N 40° 36' 12.79"; plane, on soil, 809 m, E 33° 36' 5.90" - N 40° 36' 08.08"; northeast aspect, on concrete, 751 m, E 33° 36' 25.82" - N 40° 36' 18.45" – Riversides, plane, on wall, 716 m, E 33° 37' 14.37" - N 40° 35' 32.11", and life form: Tf.

49. *Bryum caespiticium* Hedw. – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Tf.

50. *Bryum capillare* Hedw. – Protected areas, northeast aspect, on soil, 791 m, E 33° 35' 51.55" - N 40° 38' 34.74"; southeast aspect, on soil, 770 m, E 33° 36' 16.23" - N 40° 36' 15.81"; northeast aspect, on concrete, 751 m, E 33° 36' 25.78" - N 40° 36' 18.22"; east aspect, on soil, 753 m, E 33° 36' 27.07" - N 40° 35' 51.65" – Riversides, north aspect, on soil, 814 m, E 33° 36' 03.07" - N 40° 35' 36.76" – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Tf.

51. *Bryum pallens* Sw. ex anon. – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Ts.

52. *Bryum torquescens* Bruch & Schimp. – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 38' 37.49", and life form: Tf.

#### **AMBLYSTEGIACEAE**

53. *Amblystegium serpens* (Hedw.) Schimp. – Modern city, northeast aspect, on tree (*Amygdalus* sp.), 728 m, E 33° 36' 30.38" - N 40° 35' 51.09" – Protected areas, southeast aspect, on soil, 752 m, E 33° 36' 19.33" - N 40° 36' 15.82"; northeast aspect, on tree (*Robinia pseudoacacia*), 809 m, E 33° 35' 49.04" - N 40° 36' 11.25" – Uncultivated areas, north aspect, on shrub (*Berberis* sp.), 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Mr.

54. *Amblystegium subtile* (Hedw.) Schimp. – Uncultivated areas, north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Mr.

55. *Hygroamblystegium humile* (P.Beauv.) Vanderp., Goffinet & Hedenäs - Protected areas, east aspect, on soil, 769 m, E 33° 35' 53.16" - N 40° 38' 43.98"; east aspect, on soil, 772 m, E 33° 35' 53.58" - N 40° 38' 43.94", and life form: Mr.

56. *Hygroamblystegium tenax* (Hedw.) Jenn. – Uncultivated areas, southeast aspect, on concrete, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Mr.

#### **BRACHYTHECIACEAE**

57. *Rhynchostegiella litorea* (De Not.) Limpr. – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on tree (*Pyrus elaeagnifolia*), 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Mr.

58. *Sciuro-hypnum populeum* (Hedw.) Ignatov & Huttunen – Uncultivated areas, southeast aspect, on rock, 788 m, E 33° 35' 54.32" - N 40° 38' 44.17", and life form: Mr.

59. *Brachythecium albicans* (Hedw.) Schimp. – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Mr.

60. *Brachythecium erythrorrhizon* Schimp. – Modern city, east aspect, on soil, 772 m, E 33° 35' 52.57" - N 40° 38' 49.11"; northeast aspect, on soil, 728 m, E 33° 36' 30.38" - N 40° 35' 51.09" – Protected areas, east aspect, on soil, 767 m, E 33° 35' 53.55" - N 40° 38' 43.91"; north aspect, on soil, 709 m, E 33° 37' 22.59" - N 40° 35' 28.23"; northeast aspect, on soil, 745 m, E 33° 36' 28.30" - N 40° 35' 50.77"; northeast aspect, on tree, 750 m, E 33° 36' 27.23" - N 40° 35' 50.52" – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 38' 37.49", and life form: Mr.

61. *Brachythecium salebrosum* (Hoffm. ex F.Weber & D.Mohr) Schimp. – Uncultivated areas, north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Mr.

62. *Eurhynchiastrum pulchellum* (Hedw.) Ignatov & Huttunen – Protected areas, south aspect, on concrete, 692 m, E 33° 36' 58.81" - N 40° 36' 05.69"; south aspect, on soil, 692 m, E 33° 36' 58.69" - N 40° 36' 06.63" – Uncultivated areas, north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Mr.

63. *Homalothecium lutescens* (Hedw.) H.Rob. – Uncultivated areas, north aspect, on soil, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Mr.

64. *Homalothecium sericeum* (Hedw.) Schimp. – Riversides, north aspect, on soil, 805 m, E 33° 36' 08.35" - N 40° 35' 37.51"; east aspect, on rock, 797 m, E 33° 36' 07.94" - N 40° 35' 39.20"; Uncultivated areas, northeast aspect, on soil, 806 m, E 33° 35' 49.04" - N 40° 36' 11.25"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60", and life form: Mr.

#### HYPNACEAE

65. *Hypnum cupressiforme* Hedw. var. *cupressiforme* – Protected areas, northeast aspect, on soil, 779 m, E 33° 35' 54.34" - N 40° 38' 37.58" - Riversides, north aspect, on soil, 805 m, E 33° 36' 08.10" - N 40° 35' 37.58"; plane, on soil, 808 m, E 33° 36' 05.12" - N 40° 35' 37.92" – Uncultivated areas, north aspect, on rock, 755 m, E 33° 36' 25.26" - N 40° 35' 58.12"; north aspect, on soil, 793 m, E 33° 36' 10.65" - N 40° 35' 37.60"; north aspect, on rock, 810 m, E 33° 36' 07.04" - N 40° 35' 38.33", and life form: Ms.

66. *Hypnum cupressiforme* var. *lacunosum* Brid. – Protected areas, northeast aspect, on soil, 772 m, E 33° 35' 54.43" - N 40° 38' 37.42", and life form: Mr.

Among the families, Pottiaceae, Brachytheciaceae, Grimmiaceae, Orthotrichaceae and Bryaceae comprise nearly the 83.3% of the total taxa, whereas the remaining five families share 16.7%. Pokorny et al. (2006) found that the families Pottiaceae, Brachytheciaceae, Grimmiaceae, Amblystegiaceae, and Orthotrichaceae constitute the 70% of the total catalogue in Trento (North Italy). In their study,

four families are the same of us. Funariaceae is represented by only one taxon in our study. Like in other studies; Polytrichaceae in the city of Aydın (Kirmaci and Ağcagil, 2009), Dicranaceae, Funariaceae, Lembophyllaceae, Leskeaceae, and Mniaceae representing each by only one species in Belgrade are reported as monotypically (Grdović and Stevanović, 2006).



Acrocarp mosses (52 taxa) constitute 78.8% of the urban flora whereas pleurocarps (14 taxa) is 21.2%. These proportions are similar to the results of the different studies (Lo Giudice et al., 1997; Grdović and Stevanović 2006; Pokorny et al., 2006; Sabovljević and Grdović 2009; Kirmaci and Ağcagil 2009; Drugova, 2010). Skudnik et al. (2013) reported that the acrocarps and pleurocarps have the same ratio within the moss diversity of Ljubljana.

Most moss taxa found in the city of Çankırı grow on soil and *Ceratodon purpureus* and *Syntrichia ruralis* are the most common taxa on this substrate. *Tortula muralis* on man-made substrates (concrete, asphalt, and stone wall), *Grimmia trichophylla* on rocks and *Orthotrichum diaphanum* on trees were frequently reported.

The most frequent and abundant taxa are *Ceratodon purpureus* (in 23 different locality), *Syntrichia ruralis* (17), *Grimmia trichophylla* (11), *Bryum argenteum* (11), and *Tortula subulata* (10). Hill et al. (1992) reported that the *B. argenteum*, *Grimmia pulvinata*, and *Tortula muralis* are frequently encountered in urban ecosystems. Fojcik and Stebel (2006) recorded that *Dicranella varia* occurred in 39 different localities and it was the most frequent taxa within the city of Katowice in Poland. Besides, they emphasized that the moss is a good example adapted to urban conditions. Grdović and Stevanović (2006) ranged the most frequently observed mosses as *B. argenteum*, *C. purpureus*, *T. muralis*, *Funaria hygrometrica*, *Bryum caespitium*, *Bryum bicolor*, *Amblystegium serpens*, *Eurhynchium hians* var. *swartzii*, *Barbula unguiculata*, *Bryum kunzei*, and *G. pulvinata*. Pokorny et al. (2006) reported that the

most frequent and abundant taxa in Trento are; *A. serpens*, *B. unguiculata*, *Brachythecium rutabulum*, *B. argenteum*, *Bryum laevifilum*, *Bryum radiculosum*, *Didymodon rigidulus*, *E. hians*, *F. hygrometrica*, *G. pulvinata*, *Hypnum cupressiforme*, *Hypnum resupinatum*, *Leskea polycarpa*, *Orthotrichum diaphanum*, *Orthotrichum schimperi*, *Orthotrichum obtusifolium*, *Plagiomnium cuspidatum*, *Schistidium elegantulum*, *Syntrichia laevipila*, *Syntrichia papillosa*, and *T. muralis*. Mosses recorded from aforementioned countries show similarity to our results such as *C. purpureus* and *B. argenteum*. Soria and Ron (1995) indicated that 12 mosses are identified with urban conditions in Spain. Among these, seven ones *B. unguiculata*, *B. argenteum*, *Bryum capillare*, *F. hygrometrica*, *G. pulvinata*, *O. diaphanum*, and *T. muralis* were determined from Çankırı.

The existence of vegetative and generative organs in bryophytes is important to adaptation to urban conditions. The presence of sporophyte bearing mosses was recorded in 104 (44.2%) of all collected taxa. There are seven pleurocarps and 97 acrocarps in 104. The most sporophyte bearing species are *T. muralis* (13 samples), *F. hygrometrica* (8), *G. trichophylla* (8), *Tortula subulata* (7), *O. diaphanum* (6) and *Tortula inermis* (6), respectively. Pokorny et al. (2006) found that the number of sporophyte bearing species was 59 of 136 bryophytes in Trento. Sabovljević and Sabovljević (2009) recorded the percentage of mosses with sporophyte was 22.2% in pleurocarps, and 9.8% in acrocarps in Cologne.

Increasing industrializations in urban areas and vicinity brought pollutions and human impacts on biodiversity. Like cryptogams are very sensitive and less

tolerances to pollutions than the higher plants (Lo Giudice et al., 1997; Smith et al., 2010). The presence and distributions of plants are generally affected by sulphur dioxide (SO<sub>2</sub>), and suspended particulate matter (PM10) in urban ecosystems (Pokorný et al., 2006). *Weissia controversa* occurred in Mechanical and Chemical Industry Corporation on the road of Yapraklı town and *F. hygrometrica* in the vicinity of petrol station near main road of Ankara city. Similarly, Drugova (2010) mentioned four moss species registered in the vicinity of industrial zone of Monchegorsk. *F. hygrometrica* is common in both Çankırı and Monchegorsk. Bargagli (1998) stated that *F. hygrometrica* is excessively resistant to SO<sub>2</sub> and can grow on areas polluted by heavy metals. In Çankırı, *F. hygrometrica* collected from nine localities was observed on sidewalks, stone walls, and soils in open areas.

Intensive air pollution, buildings, and the loss of natural habitat in urban area are unfavorable for epiphytic taxa (Lo Giudice et al., 1997). Seven epiphytic mosses were recorded in all zones within the urban area of Çankırı. Epiphytic taxa determined from the nursery of Çankırı located in exurban are *O. diaphanum*, *Orthotrichum lyellii*, and *Orthotrichum affine*. When considered the other localities in the study area, *O. diaphanum* was the most common on trees. *B. unguiculata*, *A. serpens*, *Brachythecium erythrorrhizon*, and *Rhynchostegiella litorea* were encountered as the other epiphytes. Host species colonized by the epiphytic taxa were *Morus* sp., *Malus* sp., *Robinia pseudoacacia* L., *Cedrus libani* A. Rich., *Pyrus elaeagnifolia* Pall., *Berberis* sp., *Platycladus orientalis* L., *Platanus orientalis* L., and *Aesculus*

*hippocastanum* L. Fudali (2012) recorded 34 moss species from tree trunks in urban parks of Wrocław. Among them, *O. diaphanum* and *C. purpureus* were frequently recorded. Besides, *Quercus robur* L., *Fraxinus excelsior*, *Acer platanoides* L., cultivars of *Populus* L., and *Betula pendula* Roth. were also the host species. Drugova (2010) found that the number of the epiphytes was four and they were *Bryum pseudotriquetrum*, *Pohlia nutans*, *Sciuro-hypnum reflexum*, and *Sciuro-hypnum starkei*.

Finally, the results of the Çankırı sample is similar to many urban bryofloristic studies conducted on different countries in terms of the abundance of acrocarp mosses and a good representation of the family Pottiaceae. This circumstance is explained by the abundance of sunny habitats, life forms and reproduction abilities of the members belonging to Pottiaceae, and also better endurance against urbanization and pollution due to the their physiological tolerance (Rao, 1982; Soria and Ron 1995; Lo Giudice et al., 1997).

#### 4.2. Determinants of Moss Species Occurrence

Life forms and gametophyte structures were the mainly factors to have significant effects on the occurrence of mosses within the urban area. Respectively, these categorical variables represented 23.5% and 17.6% of the variation in moss occurrence. The most dominant factor was old city (zone 1) where not seen pleurocarpous mosses. Modern city (zone 2) was also the other overriding factor for the moss occurrence. Only two pleurocarps (*A. serpens* and *B. erythrorrhizon*) were recorded from zone 2 without sporophytes.



### 4.3. Interpretation of Categorical Variables by Chi-square Analysis

Statistical relationships between the collected mosses and some categorical variables belonging to them were evaluated by chi-square analysis shown in Table 1. Accordingly, forty-five mosses of 235 collected from the study area were correlated with the categorical variables at 0.05 significance level. The reason of the taxa not correlated with any variables but occurred in different substrates could be explained by the effects of ignored factors or showing a random distribution of the taxa.

### 4.4. Mosses and Urban Zones

Table 2 shows the moss taxa occurring within the five urban zones, their sporophyte status and life forms. Five mosses were found in zone 1. Excepting Pottiaceae, all the families represented by one moss species in this zone. While the number of sporophyte bearing species was four, only *B. argenteum* has no sporophyte. Eleven moss taxa were collected in zone 2. The family including highest taxa number was Pottiaceae. The remaining ones have one species as like in zone 1. Seven taxa were not bearing sporophyte, three mosses have sporophyte, and only *C. purpureus* had both sporophyte and no sporophyte. Thirty seven taxa were determined in zone 3. Pottiaceae was the most dominant family with 22 taxa. The most collected taxa were *G. trichophylla*, *Tortella inclinata* var. *densa*, and *Tortula inermis*. Sixteen taxa with sporophyte, 18 taxa with no sporophyte,

and three of 37 had both sporophyte and none were noted. Thirteen mosses were found in zone 4. Pottiaceae and Grimmiaceae were the most dominant families represented by five and three taxa, respectively. *S. ruralis* was recorded as the most collected species. Forty six taxa were recorded in zone 5 and this zone seems to be more favorable to mosses in terms of the diversity. *B. capillare*, *G. trichophylla*, *H. cupressiforme*, *S. ruralis* and *T. muralis* constitute the most collected taxa.

As a consequence of life forms analysis of the urban mosses, following ranking was obtained from the most resistant to the least in relation to tolerance to urban conditions, as in different studies (Gilbert, 1970; Lo Giudice et al., 1997): Tf > Mr > Cu > Tuft > Ts > Ms. Lo Giudice et al. (1997) proposed the most preferred life form is short turf, and the least dendroid in Enna. In Çankırı, the Tf typed mosses represented about 4.5% of the total taxa in zone 1, 10.6% in zone 2, 31.8% in zone 3, 10.6% in zone 4, and 27.3% in zone 5. Likewise, the most resistant life form Tf, i.e. vertical stems with little or no branching, was observed as higher proportion than the other type forms in all zones. However, the least preferred life form Ms, i.e. creeping, branches lying flat, was shown in zones 3 and 4. Besides the environmental factors involved in moss life form, obtained data from the five zones established within the urban area of Çankırı supported the influence of urban conditions of the study area.

**Table 1.** Mosses correlated with the categorical variables based on the results of chi-square analysis

Moss taxa	CATEGORICAL VARIABLES							
	Locality	Zone	Aspect	Life Form	Gametophyte Structure	Sporophyte	Slope Classes	Altitude Classes
<i>Amblystegium serpens</i>	$\chi^2=66,074$	$\chi^2=2,115$	$\chi^2=3,463$	$\chi^2=25,814^*$	$\chi^2=20,451^*$	$\chi^2=1,559$	$\chi^2=1,104$	$\chi^2=0,822$
<i>Amblystegium subtile</i>	$\chi^2=2,683$	$\chi^2=1,332$	$\chi^2=1,839$	$\chi^2=6,371$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=2,101$	$\chi^2=1,618$
<i>Barbula convoluta</i>	$\chi^2=46,197$	$\chi^2=1,647$	$\chi^2=22,596^*$	$\chi^2=0,744$	$\chi^2=0,200$	$\chi^2=0,797$	$\chi^2=5,739$	$\chi^2=1,265$
<i>Barbula unguiculata</i>	$\chi^2=182,704^*$	$\chi^2=5,120$	$\chi^2=2,711$	$\chi^2=3,014$	$\chi^2=0,810$	$\chi^2=0,612$	$\chi^2=9,053$	$\chi^2=4,870$
<i>Brachythecium albicans</i>	$\chi^2=2,683$	$\chi^2=1,332$	$\chi^2=1,839$	$\chi^2=6,371$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=2,101$	$\chi^2=1,618$
<i>Brachythecium erythrorrhizon</i>	$\chi^2=79,350^*$	$\chi^2=6,633$	$\chi^2=6,166$	$\chi^2=45,770^*$	$\chi^2=36,260^*$	$\chi^2=5,728^*$	$\chi^2=11,764^*$	$\chi^2=2,338$
<i>Brachythecium salebrosum</i>	$\chi^2=2,683$	$\chi^2=1,332$	$\chi^2=1,839$	$\chi^2=45,770$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=2,101$	$\chi^2=1,618$
<i>Bryum argenteum</i>	$\chi^2=155,310^*$	$\chi^2=17,824^*$	$\chi^2=6,660$	$\chi^2=6,371$	$\chi^2=2,296$	$\chi^2=5,784^*$	$\chi^2=14,364^*$	$\chi^2=13,808^*$
<i>Bryum pallens</i>	$\chi^2=2,683$	$\chi^2=1,332$	$\chi^2=1,839$	$\chi^2=38,330^*$	$\chi^2=0,200$	$\chi^2=1,265$	$\chi^2=2,101$	$\chi^2=1,618$
<i>Ceratodon purpureus</i>	$\chi^2=69,399$	$\chi^2=1,395$	$\chi^2=7,984$	$\chi^2=18,885^*$	$\chi^2=5,073^*$	$\chi^2=13,068^*$	$\chi^2=15,915^*$	$\chi^2=5,368$
<i>Eurhynchiastrum pulchellum</i>	$\chi^2=156,894^*$	$\chi^2=1,313$	$\chi^2=43,258^*$	$\chi^2=19,277^*$	$\chi^2=15,272^*$	$\chi^2=0,147$	$\chi^2=6,357$	$\chi^2=6,659$
<i>Funaria hygrometrica</i>	$\chi^2=138,463^*$	$\chi^2=21,959^*$	$\chi^2=8,328$	$\chi^2=6,932$	$\chi^2=1,862$	$\chi^2=11,788^*$	$\chi^2=5,653$	$\chi^2=28,804^*$
<i>Grimmia anodon</i>	$\chi^2=5,390$	$\chi^2=2,676$	$\chi^2=3,694$	$\chi^2=11,527^*$	$\chi^2=0,401$	$\chi^2=2,541$	$\chi^2=4,220$	$\chi^2=3,250$
<i>Grimmia funalis</i>	$\chi^2=18,663$	$\chi^2=12,107^*$	$\chi^2=1,839$	$\chi^2=5,739$	$\chi^2=0,200$	$\chi^2=0,797$	$\chi^2=3,366$	$\chi^2=1,618$
<i>Grimmia orbicularis</i>	$\chi^2=5,390$	$\chi^2=2,676$	$\chi^2=3,694$	$\chi^2=11,527^*$	$\chi^2=0,401$	$\chi^2=2,541$	$\chi^2=4,220$	$\chi^2=3,250$
<i>Grimmia pulvinata</i>	$\chi^2=52,181$	$\chi^2=1,619$	$\chi^2=2,075$	$\chi^2=29,193^*$	$\chi^2=1,017$	$\chi^2=2,646$	$\chi^2=2,348$	$\chi^2=1,489$
<i>Grimmia trichophylla</i>	$\chi^2=36,968$	$\chi^2=2,084$	$\chi^2=5,693$	$\chi^2=65,944^*$	$\chi^2=2,296$	$\chi^2=3,792$	$\chi^2=2,720$	$\chi^2=3,004$
<i>Homalothecium lutescens</i>	$\chi^2=2,683$	$\chi^2=1,332$	$\chi^2=1,839$	$\chi^2=6,371$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=2,101$	$\chi^2=1,618$
<i>Homalothecium sericeum</i>	$\chi^2=17,289$	$\chi^2=9,142$	$\chi^2=5,079$	$\chi^2=39,060^*$	$\chi^2=30,944^*$	$\chi^2=4,888^*$	$\chi^2=11,325^*$	$\chi^2=9,920^*$
<i>Hygroamblystegium humile</i>	$\chi^2=57,237$	$\chi^2=3,309$	$\chi^2=14,913^*$	$\chi^2=12,796^*$	$\chi^2=10,138^*$	$\chi^2=1,601$	$\chi^2=11,527^*$	$\chi^2=2,541$
<i>Hygroamblystegium tenax</i>	$\chi^2=9,257$	$\chi^2=1,332$	$\chi^2=5,374$	$\chi^2=6,371$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=3,366$	$\chi^2=1,265$
<i>Hypnum cupressiforme</i> var. <i>cupressiforme</i>	$\chi^2=45,608$	$\chi^2=6,345$	$\chi^2=5,781$	$\chi^2=235,000^*$	$\chi^2=36,260^*$	$\chi^2=5,728^*$	$\chi^2=4,201$	$\chi^2=3,728$
<i>Hypnum cupressiforme</i> var. <i>lacunosum</i>	$\chi^2=11,417$	$\chi^2=1,647$	$\chi^2=4,126$	$\chi^2=6,371$	$\chi^2=5,047^*$	$\chi^2=0,797$	$\chi^2=5,739$	$\chi^2=1,265$

\*: p<0,05, at 95% significance levels



Table 1 is continued

Moss taxa	CATEGORICAL VARIABLES							
	Locality	Zone	Aspect	Life Form	Gametophyte Structure	Sporophyte	Slope Classes	Altitude Classes
<i>Orthotrichum affine</i>	$\chi^2 = 18,593$	$\chi^2 = 6,76$	$\chi^2 = 10,795$	$\chi^2 = 11,527^*$	$\chi^2 = 0,401$	$\chi^2 = 1,601$	$\chi^2 = 6,761$	$\chi^2 = 2,541$
<i>Orthotrichum diaphanum</i>	$\chi^2 = 39,890$	$\chi^2 = 2,016$	$\chi^2 = 15,727^*$	$\chi^2 = 35,184^*$	$\chi^2 = 1,225$	$\chi^2 = 7,756^*$	$\chi^2 = 7,958$	$\chi^2 = 4,621$
<i>Pleurochaete squarrosa</i>	$\chi^2 = 14,005$	$\chi^2 = 1,649$	$\chi^2 = 3,096$	$\chi^2 = 3,784$	$\chi^2 = 1,017$	$\chi^2 = 4,056^*$	$\chi^2 = 4,171$	$\chi^2 = 1,181$
<i>Protobryum bryoides</i>	$\chi^2 = 116,998^*$	$\chi^2 = 1,647$	$\chi^2 = 4,126$	$\chi^2 = 0,744$	$\chi^2 = 0,200$	$\chi^2 = 1,265$	$\chi^2 = 5,739$	$\chi^2 = 1,265$
<i>Pterygoneurum ovatum</i>	$\chi^2 = 13,338$	$\chi^2 = 1,479$	$\chi^2 = 6,601$	$\chi^2 = 194,982^*$	$\chi^2 = 1,017$	$\chi^2 = 6,435^*$	$\chi^2 = 8,792$	$\chi^2 = 0,207$
<i>Rhynchostegiella litorea</i>	$\chi^2 = 8,119$	$\chi^2 = 4,032$	$\chi^2 = 5,565$	$\chi^2 = 19,277^*$	$\chi^2 = 15,272^*$	$\chi^2 = 3,828^*$	$\chi^2 = 6,357$	$\chi^2 = 4,896$
<i>Schistidium apocarpum</i>	$\chi^2 = 5,390$	$\chi^2 = 2,676$	$\chi^2 = 3,694$	$\chi^2 = 21,685^*$	$\chi^2 = 0,401$	$\chi^2 = 0,027$	$\chi^2 = 4,220$	$\chi^2 = 3,250$
<i>Sciuro-hypnum populeum</i>	$\chi^2 = 9,257$	$\chi^2 = 1,332$	$\chi^2 = 5,374$	$\chi^2 = 6,371$	$\chi^2 = 5,047^*$	$\chi^2 = 0,797$	$\chi^2 = 3,366$	$\chi^2 = 1,265$
<i>Syntrichia papillosissima</i>	$\chi^2 = 11,417$	$\chi^2 = 1,647$	$\chi^2 = 37,711^*$	$\chi^2 = 10,796$	$\chi^2 = 0,200$	$\chi^2 = 0,797$	$\chi^2 = 2,101$	$\chi^2 = 1,618$
<i>Syntrichia caninervis</i> var. <i>caninervis</i>	$\chi^2 = 90,772^*$	$\chi^2 = 1,313$	$\chi^2 = 12,086$	$\chi^2 = 2,251$	$\chi^2 = 0,605$	$\chi^2 = 2,412$	$\chi^2 = 3,404$	$\chi^2 = 15,916^*$
<i>Syntrichia caninervis</i> var. <i>gypsophila</i>	$\chi^2 = 75,620^*$	$\chi^2 = 0,984$	$\chi^2 = 17,295^*$	$\chi^2 = 3,014$	$\chi^2 = 0,810$	$\chi^2 = 3,231$	$\chi^2 = 3,274$	$\chi^2 = 11,843^*$
<i>Syntrichia montana</i>	$\chi^2 = 116,998^*$	$\chi^2 = 1,647$	$\chi^2 = 4,126$	$\chi^2 = 10,796$	$\chi^2 = 0,200$	$\chi^2 = 0,797$	$\chi^2 = 5,739$	$\chi^2 = 1,265$
<i>Syntrichia ruralis</i> var. <i>ruralis</i>	$\chi^2 = 51,475$	$\chi^2 = 8,548$	$\chi^2 = 15,336^*$	$\chi^2 = 13,575^*$	$\chi^2 = 3,646$	$\chi^2 = 10,938^*$	$\chi^2 = 7,862$	$\chi^2 = 2,635$
<i>Syntrichia ruralis</i> var. <i>ruraliformis</i>	$\chi^2 = 27,610$	$\chi^2 = 5,898$	$\chi^2 = 3,643$	$\chi^2 = 1,494$	$\chi^2 = 0,401$	$\chi^2 = 1,601$	$\chi^2 = 4,220$	$\chi^2 = 23,001^*$
<i>Tortella inclinata</i> var. <i>densa</i>	$\chi^2 = 34,546$	$\chi^2 = 4,985$	$\chi^2 = 6,695$	$\chi^2 = 32,667^*$	$\chi^2 = 0,605$	$\chi^2 = 3,828$	$\chi^2 = 8,620$	$\chi^2 = 0,895$
<i>Tortula brevisissima</i>	$\chi^2 = 33,907$	$\chi^2 = 1,313$	$\chi^2 = 7,996$	$\chi^2 = 2,251$	$\chi^2 = 0,605$	$\chi^2 = 3,828^*$	$\chi^2 = 2,360$	$\chi^2 = 0,895$
<i>Tortula canescens</i>	$\chi^2 = 175,233^*$	$\chi^2 = 2,354$	$\chi^2 = 3,230$	$\chi^2 = 3,014$	$\chi^2 = 0,810$	$\chi^2 = 3,231$	$\chi^2 = 28,629^*$	$\chi^2 = 2,763$
<i>Tortula inermis</i>	$\chi^2 = 80,270^*$	$\chi^2 = 4,128$	$\chi^2 = 7,758$	$\chi^2 = 6,932$	$\chi^2 = 1,862$	$\chi^2 = 1,905$	$\chi^2 = 3,809$	$\chi^2 = 2,001$
<i>Tortula muralis</i>	$\chi^2 = 74,371$	$\chi^2 = 2,478$	$\chi^2 = 7,409$	$\chi^2 = 10,194$	$\chi^2 = 2,738$	$\chi^2 = 17,334^*$	$\chi^2 = 6,980$	$\chi^2 = 6,732$
<i>Tortula subulata</i>	$\chi^2 = 124,934^*$	$\chi^2 = 9,152$	$\chi^2 = 22,574^*$	$\chi^2 = 112,278^*$	$\chi^2 = 2,078$	$\chi^2 = 2,806$	$\chi^2 = 2,145$	$\chi^2 = 4,120$
<i>Tortula vahliana</i>	$\chi^2 = 175,746^*$	$\chi^2 = 5,552$	$\chi^2 = 21,150^*$	$\chi^2 = 1,494$	$\chi^2 = 0,401$	$\chi^2 = 0,027$	$\chi^2 = 5,115$	$\chi^2 = 2,414$
<i>Weissia controversa</i>	$\chi^2 = 235,000^*$	$\chi^2 = 1,647$	$\chi^2 = 32,711^*$	$\chi^2 = 0,744$	$\chi^2 = 0,200$	$\chi^2 = 1,265$	$\chi^2 = 3,366$	$\chi^2 = 1,265$

\*: p&lt;0,05, at 95% significance levels

**Table 2.** Moss occurrence in urban zones, with their life forms.

Moss Taxa	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Life forms
<i>Encalypta rhaptocarpa</i>	-	-	-	-	S	Tuft
<i>Encalypta vulgaris</i>	-	-	S	-	-	Tf
<i>Funaria hygrometrica</i>	S	S	S	-	-	Tf
<i>Grimmia anodon</i>	-	-	-	-	S	Cu
<i>Grimmia donniana</i>	-	-	-	-	Ns	Cu
<i>Grimmia funalis</i>	-	-	-	Ns	-	Cu
<i>Grimmia orbicularis</i>	-	-	-	-	S	Cu
<i>Grimmia pulvinata</i>	-	-	S	Ns	S	Cu
<i>Grimmia trichophylla</i>	S	-	Sns	Ns	S	Cu
<i>Schistidium apocarpum</i>	-	-	-	-	Sns	Tuft
<i>Ceratodon purpureus</i>	-	Sns	Ns	Ns	Ns	Tf
<i>Ditrichum flexicaule</i>	-	-	-	-	Ns	Tuft
<i>Pleurochaete squarrosa</i>	-	-	Ns	-	Ns	Tf
<i>Tortella inclinata</i> var. <i>densa</i>	-	-	S	-	-	Tuft
<i>Tortella tortuosa</i>	-	-	S	-	-	Tuft
<i>Weissia condensata</i>	-	-	-	-	Ns	Tf
<i>Weissia controversa</i>	-	-	S	-	-	Tf
<i>Barbula convoluta</i>	-	-	Ns	-	-	Tf
<i>Barbula unguiculata</i>	-	Ns	Sns	-	-	Tf
<i>Crossidium crassinerve</i>	-	-	-	Ns	S	Tf
<i>Crossidium squamiferum</i> var. <i>pottioideum</i>	-	-	-	-	S	Tf
<i>Didymodon tophaceus</i>	-	-	S	-	-	Tf
<i>Protobryum bryoides</i>	-	-	S	-	-	Tf
<i>Pseudocrossidium revolutum</i>	-	-	-	-	S	Tf
<i>Pterygoneurum ovatum</i>	-	S	S	-	S	Ts
<i>Syntrichia caninervis</i> var. <i>caninervis</i>	-	-	Ns	-	Ns	Tf
<i>Syntrichia caninervis</i> var. <i>gypsophila</i>	-	-	Ns	-	Ns	Tf
<i>Syntrichia latifolia</i>	-	-	S	-	-	Tf
<i>Syntrichia montana</i>	-	-	Ns	-	-	Tuft
<i>Syntrichia papillosissima</i>	-	-	Ns	-	-	Tuft
<i>Syntrichia ruralis</i> var. <i>ruralis</i>	-	-	Ns	Ns	Sns	Tf
<i>Syntrichia ruralis</i> var. <i>ruraliformis</i>	-	-	Ns	Ns	-	Tf
<i>Tortula brevissima</i>	-	-	S	-	S	Tf
<i>Tortula canescens</i>	-	Ns	Ns	-	Ns	Tf
<i>Tortula inermis</i>	-	-	Ns	-	S	Tf
<i>Tortula lanceola</i>	-	-	-	-	S	Tf
<i>Tortula modica</i>	-	-	-	-	S	Tf
<i>Tortula muralis</i>	S	S	S	S	S	Tf
<i>Tortula subulata</i>	S	Ns	Sns	S	Sns	Tuft
<i>Tortula vahliana</i>	-	Ns	S	-	-	Tf
<i>Orthotrichum anomalum</i>	-	-	-	-	S	Cu
<i>Orthotrichum cupulatum</i>	-	-	-	-	Ns	Cu
<i>Orthotrichum urnigerum</i>	-	-	S	-	-	Cu
<i>Orthotrichum diaphanum</i>	-	-	S	-	S	Cu
<i>Orthotrichum rupestre</i>	-	-	-	-	Ns	Cu
<i>Orthotrichum affine</i>	-	-	-	-	Ns	Cu
<i>Orthotrichum lyellii</i>	-	-	-	-	Ns	Cu

**S:** with sporophytes; **Ns:** no sporophytes; **Sns:** with and without sporophytes; (-): taxon absent in the zone; **Cu:** Cushion; **Mr:** Mat, rough; **Ms:** Mat, smooth; **Tf:** Turf; **Ts:** Turf, scattered



Table 2 is continued

Moss Taxa	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Life forms
<i>Bryum argenteum</i>	Ns	Ns	Ns	Ns	-	Tf
<i>Bryum caespiticium</i>	-	-	-	-	S	Tf
<i>Bryum capillare</i>	-	-	Ns	Ns	S	Tf
<i>Bryum pallens</i>	-	-	-	-	S	Ts
<i>Bryum torquescens</i>	-	-	-	-	S	Tf
<i>Amblystegium serpens</i>	-	Ns	S	-	S	Mr
<i>Amblystegium subtile</i>	-	-	-	-	Ns	Mr
<i>Hygroamblystegium humile</i>	-	-	Ns	-	-	Mr
<i>Hygroamblystegium tenax</i>	-	-	-	-	Ns	Mr
<i>Rhynchostegiella litorea</i>	-	-	-	-	S	Mr
<i>Sciuro-hypnum populeum</i>	-	-	-	-	Ns	Mr
<i>Brachythecium albicans</i>	-	-	-	-	Ns	Mr
<i>Brachythecium erythrorrhizon</i>	-	Ns	Ns	-	Ns	Mr
<i>Brachythecium salebrosum</i>	-	-	-	-	Ns	Mr
<i>Eurhynchiastrum pulchellum</i>	-	-	Ns	-	S	Mr
<i>Homalothecium lutescens</i>	-	-	-	-	Ns	Mr
<i>Homalothecium sericeum</i>	-	-	-	Ns	Ns	Mr
<i>Hypnum cupressiforme</i> var. <i>cupressiforme</i>	-	-	Ns	Ns	Ns	Ms
<i>Hypnum cupressiforme</i> var. <i>lacunosum</i>	-	-	Ns	-	-	Mr

S: with sporophytes; Ns: no sporophytes; Sns: with and without sporophytes; (-): taxon absent in the zone; Cu: Cushion; Mr: Mat, rough; Ms: Mat, smooth; Tf: Turf; Ts: Turf, scattered

#### 4.5. Topographical Features of the Study Area

##### 4.5.1. Slope Properties

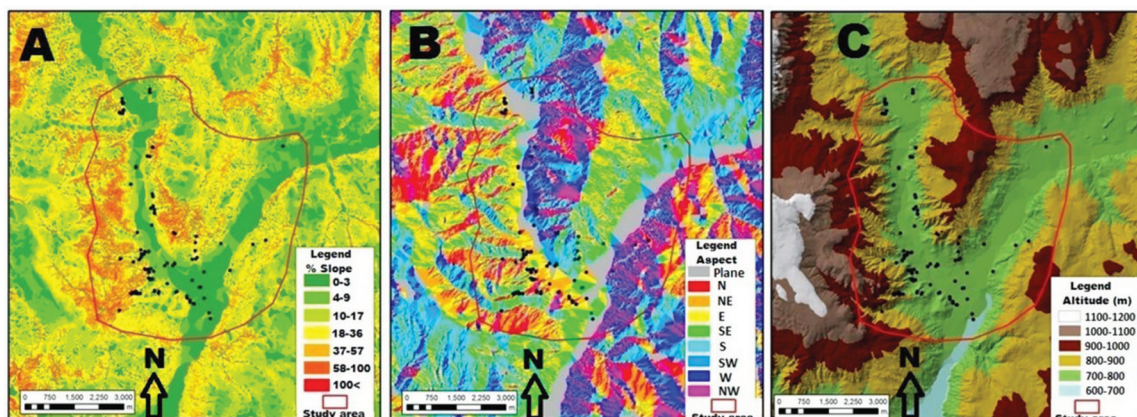
Sampling localities in the study area were generally comprised of points where the change of slope between 37-57%. Among these slope values, 76 moss taxa occurred (Fig. 3A).

##### 4.5.2. Aspect Properties

Sampling locations were often located on north aspect of the area. Eighty three mosses were collected there (Fig. 3B).

##### 4.5.3. Altitude Analysis

In order to better understanding of the topographical characteristics of the study area, three dimensional terrain models was performed. Generally, moss collected locations include the altitudes between 700-800 m (Fig. 3C).



Figures 3A-B-C. Topographical features of the study area, (A) Slope properties, (B) Aspect properties, (C) Altitude analysis

## 5. Conclusions

Urban area plays an important role of determinant of moss species distribution and richness among the environmental conditions. Life form was the most effective categorical variable in taxa distribution whereas the zones were the less one. While only one categorical variable showed a positive effect on the presence of some moss species in different habitats, multiple variables were determinative in other species. Pleurocarp structured mosses were not or rarely found in residential areas most exposed to human practices (zone 1-2). Many epiphytic taxa selected the zone 5 as more favorable habitat within all zones. This zone was a place where frequently seen the mosses with sporophytes and higher fertility, a greater diversity of life forms among

habitats. In contrast, zone 2 exhibited the less sporophyte bearing mosses. This is probably resulting from human impacts and air pollution. Previous studied urban areas support the idea.

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