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Original research

An oasis in the Central Anatolian steppe: the ecology of a collapse doline

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Abstract: In this study, the ecological properties of a collapse doline located in the steppe of Central Anatolia were determined via microclimate conditions, plant specimens, and high-resolution surface models. The collapse doline covers 8,708 m^2 and has a maximum length of 121 m and a maximum depth of 59 meters. Annual, maximum and minimum temperatures show that the inside of the doline is hotter than outside especially during the summer months. Notably, the inside of the doline has much greater humidity than outside during the winter and spring months. A total of 156 plant species were identified in the doline. Dominant phytogeographic element in doline is Irano-Turanian. The coldest and wettest part of the doline is the steep north-facing walls which are covered with bryophytes due to the influence of shadow. While shrub forms are found on the south and east-facing slopes, the west-facing slopes are covered with herbaceous forms. Due to the geographic location of the doline, the aspect and slope properties and their microclimatic effects significantly influence the number and distribution of plant species in the doline. While bryophytes shelter on the north-facing slopes and the steep walls of the doline, shrubs grow on the south and east-facing slopes and herbaceous forms favor the west-facing slopes.

Keywords: Collapse doline, micro ecology, micro climate, semi-arid, steppe

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Introduction

Dolines are diagnostic landforms found in karst areas (Ford and Williams, 2007) and they have a great importance in the tectonic and geomorphologic investigation of karst regions (Faivre and Pahernik, 2007; Öztürk et al., 2018a; Nazik et al., 2019). They also influence the vegetation, hydrology and anthropological activity in karst areas (Öztürk et al., 2018b). The bottom of a doline may be used for agriculture, settlement and herding on bare karsts (Anica and Mojca, 2010). Besides these features, dolines are described as interesting localities due to their exceptional microclimatic, ecological and vegetational attributes (Vilović et al., 2019).

The climate of dolines differs from the climate of the surrounding environment. The concave relief form of dolines favors the formation of air temperature inversion (Vilović et al., 2019). Temperature inversion occurs as a consequence of the smaller amount of received solar radiation, caused by the geomorphology of the doline (Antonic et al., 1994; Whiteman et al., 2004). The dolines are filled with a cold air lake or pool at night and with hot air by day that remains in the depression (Bárány-Kevei, 1999; Iijima and Shinoda, 2000; Steinacker et al., 2007). This microclimatic feature creates distinctive microecological conditions that may affect the distribution and abundance of species found within the doline (Iijima and Shinoda, 2000; Bátori et al., 2019). According to Horvat (1953), the cool and humid microclimate of sinkholes may affect their flora and vegetation. Different slopes in the doline tend to have different vegetation due to these microclimatic variations (Antonic et al., 1994;

Bárány-Kevei, 2011; Raschmanová et al., 2013). Also, these microclimate conditions change throughout the day and these changes strongly also influence the composition of local flora and vegetation in the doline.

Dolines harbor many vascular and non-vascular plant species that are missing or very rare in the surrounding habitat; indeed, they can be considered habitat islands especially in the semi-humid and semi-arid environments (Herault and Thoen, 2009; Batori et al., 2012; Bátori et al., 2014b). Many plants, in particular mountain species, are restricted to the bottom of dolines where appropriate environmental conditions exist (Bátori et al., 2014a). Due to these microecological conditions, many dolines have developed into an excellent refuge area for relict, mountain and endemic species (Egli et al., 1990; Brullo and del Galdo, 2001). Doline bottoms in bare karst areas may be covered by soil or lakes and the soil properties cause colonization by some plant and plankton species on the bottom of the doline (Armengol and Miracle, 1999; Brullo and del Galdo, 2001). For example, the richness of species positively correlates with soil temperature in the Western Carpathian Mountains (Raschmanová et al., 2018). Microclimate and soil properties can also change depending on the size and morphology of the doline and results in vegetation cover differences within the doline. Hence there is a strong correlation between species composition and doline morphology (Favretto and Poldini, 1985; Ozkan et al., 2010; Vilović et al., 2019) and dolines may provide primary habitats for many species absent in the surrounding vegetation (Batori et al., 2012).

For these reasons, dolines can be considered as reservoirs for many plant species and are particularly important from a conservation point of view. Moreover, dolines have a wide spatial distribution in Anatolia, especially on the Taurus Mountains, and will likely become an increasingly indispensable refuge for biodiversity under future global warming (Bátori, Csiky, et al., 2014; Öztürk, Şimşek, et al., 2018).

The morphology and morphometric properties of dolines in Anatolia are commonly used as a tectonic indicator in morphotectonic studies (Öztürk et al., 2015, 2018a). However, only one study so far has investigated the ecological conditions of dolines in Anatolia (Ozkan et al., 2010). In the present study, microecological conditions of a collapse doline in the steppe of Central Anatolia (Fig. 1) were investigated via its microclimatic features, high-resolution surface models, plant species composition and the results of field studies. In this study, field observations, microclimate analyses, geomorphological interpretation via high-resolution surface models created by unmanned air vehicles (UAV) are used together at first-time for a collapse doline in a semiarid-environment.

Material and Method

In this study, the microclimate and unmanned air vehicle surface model analyses were conducted in tandem with the identification of plant species. Field studies were performed during 12 visits with a set of dataloggers to collect microclimate data, form UAV models, and to determine plant species (Table 1).

Table 1. Timetable of field studies

No	Date	Purpose
1	20.07.2016	First exploration of doline
2	20.07.2017	Create UAV models and identify plant species
3	30.09.2017	Identify plant species
4	03.04.2018	Place dataloggers and observe plant species
5	15.04.2018	Collect microclimate data and plant species
6	17.05.2018	Collect microclimate data and plant species
7	24.07.2018	Observe plant species
8	10.07.2018	Observe plant species
9	20.07.2018	Observe plant species
10	30.09.2018	Collect microclimate data and plant species
11	06.03.2019	Observe plant species
12	09.08.2019	Observe plant species and remove dataloggers

To gather information on the microclimate, the air temperature (°C) and humidity (%) were measured for one year with two Trotec dataloggers. These dataloggers were placed in the inner and outer parts of the doline to determine the difference between inner and outer climatic conditions (Fig. 2a). Monthly data covering all twelve months were evaluated in this study.

For the aerial photographs, unmanned air vehicles (UAV) were used (DJI Phantom 3 pro and 4 Advanced) and orthophoto models were created. Digital elevation, slope and aspect models were also created using the 2017 UAV images and basic geomorphological properties were evaluated via these models.

Plant specimens were collected from the doline during a total of 11 field study trips. The specimens were identified using Flora of Turkey (Davis, 1965, 1988) for vascular plants, and The Moss Flora of Britain and Ireland (Smith, 2004) for mosses.

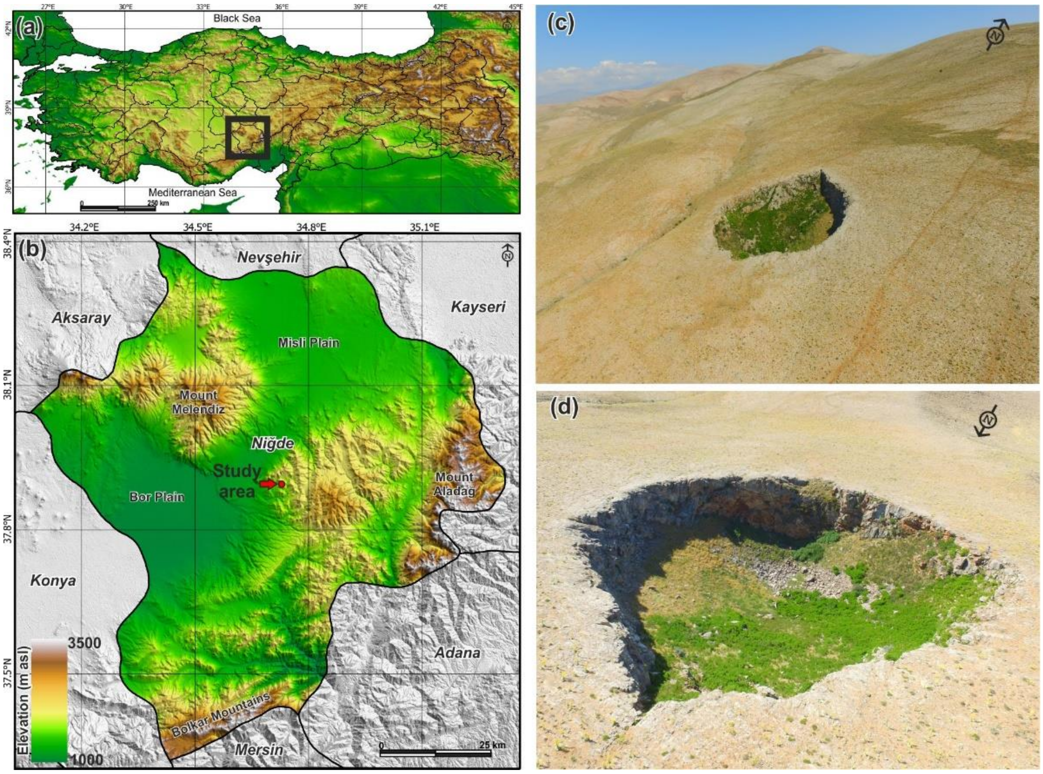

Figure 1. (a, b) Location, (c, d) aerial photos of the studied collapse doline

Study area

The study area is a collapse doline located at coordinates 651,886 m E and 4,195,488 m N (UTM zone 36) in the province of Niğde in Central Anatolia (Figs. 1 and 2a). The doline was found on a south-facing slope in marble bedrock. According to Niğde Meteorology Station (1211 m), located north of the study area (Fig. 1b), annual total precipitation is 335 mm. Niğde province has a semi-arid (steppe) climate according to Köppen-Geiger and Erinç climate classifications (Öztürk et al., 2017; Aydın et al., 2019).

The doline area was determined based on the 25° slope contour line created from the UAV model (Figs. 2b,c,d). According to this boundary, the area of the doline is 8,708 m^2. It is maximum 121 m in length in a S-N direction and 113 m in width in a W-E direction. Elevation decreases from north to south and the highest points in the north and south are 1754 and 1722 meters, respectively (Fig. 2b). The deepest point is 1695 meters. According to these results, the maximum depth of the doline is 59 meters (Figs. 2b and 3). The doline walls are very steep and slope values reach 90° (Fig. 2c). Except for the doline walls, the slope values range between 25° and 50°. The most characteristic topographic feature of the doline is its aspect. The four aspect directions (north, south, east, west) are clustered in different parts of the doline and this distribution has affected the microclimate and distribution of plant species (Fig. 2d). Additionally, the topography and aspect of the doline protect plant vegetation from strong winds. While south-facing slopes have a drier and warmer climate, the north-facing slopes (Fig. 2) and doline bottoms are cooler and more moist than the surrounding climate (Bátori et al., 2019)

Results and Discussion

Microclimate

The temperature of the doline is related to solar radiation and changes depending on geographical location and topographic features. At mid and high latitudes, a different amount of solar radiation on different slopes results in local environmental gradients (e.g. air temperature, air humidity, soil moisture), which in turn strongly influence the composition of flora and vegetation (Bátori et al., 2011). For example, due to the aspect and slope degree, the slopes on northern-facing dolines stay in shadow for a longer time and cause a strong self-shadow effect at mid to high latitudes in the northern hemisphere (Bárány-Kevei, 1998). This effect has been identified as an important factor in determining the ecological conditions in dolines (Bennie et al., 2008). While south-facing slopes receive higher solar radiation, east- and west-facing slopes receive solar radiation only at sunrise and sunset, respectively. Thus, the aspect affects air temperature, air humidity and soil moisture, and ultimately affects the vegetation (Bennie et al., 2008; Bátori et al., 2011). For example, due to the cooler climate, rock surfaces at the north-facing slope are covered by mosses in our study area. Also, the amount of radiation per surface unit is significantly modified by the angle of the slope in dolines. While insolation is intense on the south-facing slopes, the steep north-facing slopes receive almost no radiation from the sun during daylight (Fig. 3).

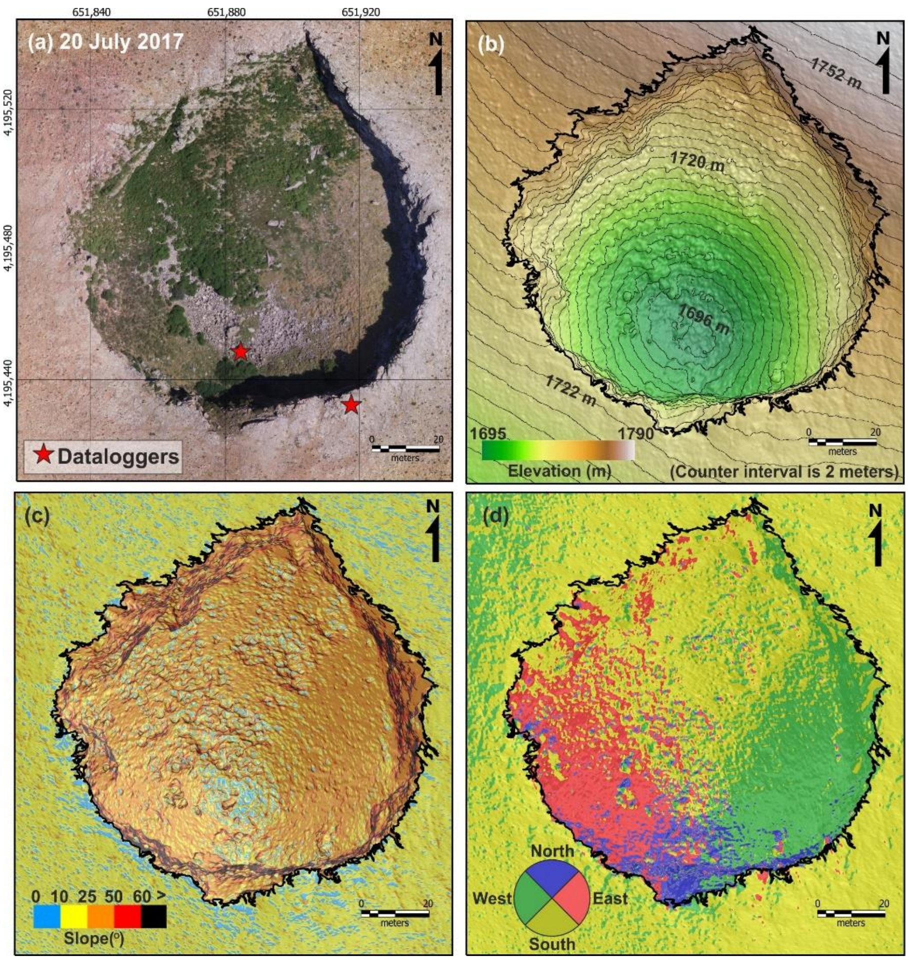

Figure 2: (a) Orthophoto, (b) elevation, (c) slope and (d) aspect models created from UAV of the doline (Black lines in b, c and d show boundary of the study area).

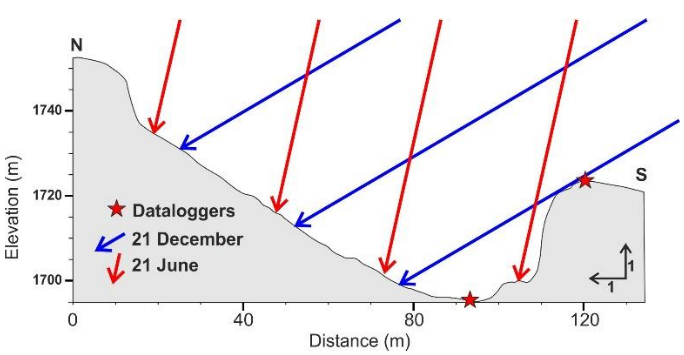

Figure 3. Angle of sun's rays within doline at the time of winter and summer solstices.

Eastern exposure receives more intensive radiation from sunrise to 9 am, then in the afternoon hours the insolation is more intense on slopes with western exposure (Bárány-Kevei, 1999). In the study area, sunlight reached the doline between 74.5° and 30.5° between 21 June and 21 December. However, because of the inner structure of the doline, the angle of sunlight changes within the doline (Fig. 3). For instance, the southernmost part of the doline receives sunlight during summer time but except for this period, the southernmost part (north-facing slopes) is under the influence of shade. This was observed during field studies. The snow cover within the doline disappears last from the southernmost part (Fig. 5c). Because of this, mosses can be seen on the walls of the north-facing slopes (Fig. 5b, c).

According to annual measurements, the average temperatures inside and outside the doline are 11°C and 12°C, respectively (Table 2). These inside and outside temperatures are almost equal during the summer period. However, inside temperatures are lower than outside during the winter (Table 1; Fig. 4a). This most likely results from the shade inside, whereby the datalogger stays in shadow for a long time during the winter period (Fig. 2a and 3).

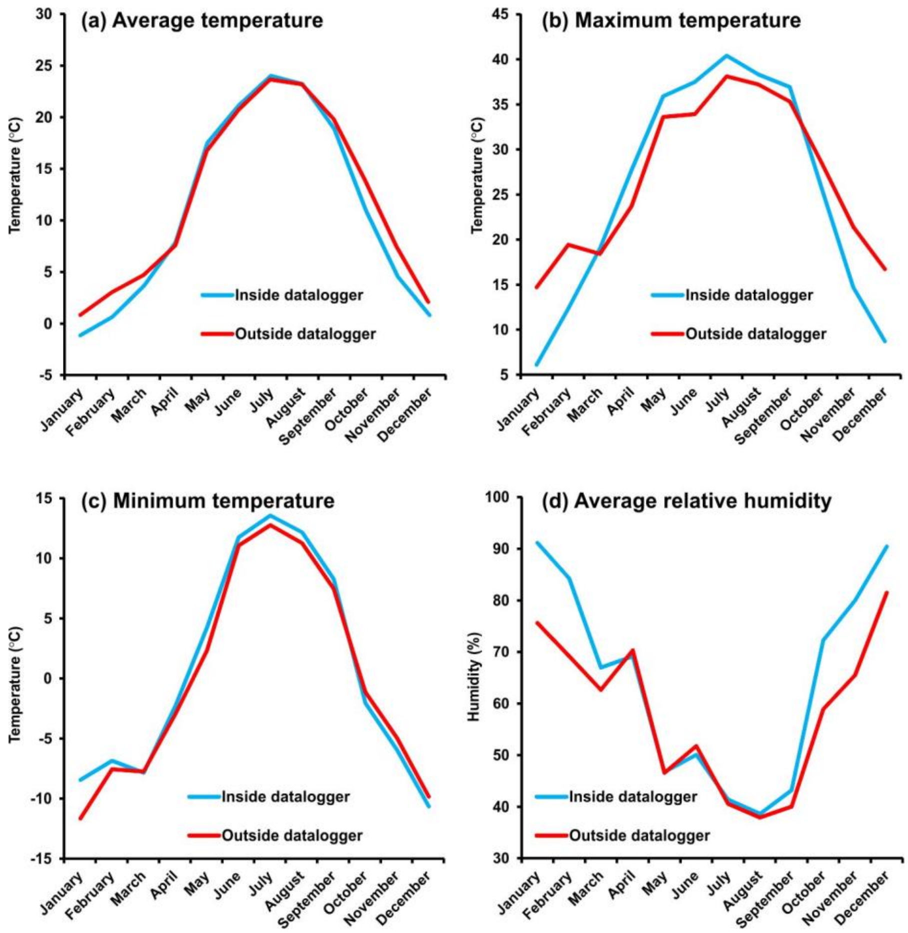

Figure 4. Change of monthly (a) average, (b) maximum and (c) minimum temperatures, (d) average humidity recorded by inside and outside dataloggers.

Maximum temperatures inside and outside the doline reach 40.4°C and 38.1°C in July, respectively (Table 2). In other words, the inside is warmer than outside at midday during the summer mouths. To the contrary, the inside is colder than outside during winter months (Fig. 4b). Maximum temperatures inside and outside are 6.1°C and 14.7°C in January, respectively. In short, the temperature differences between inside and outside the doline increase with maximum temperatures. Also, inside temperatures are more and less than the outside temperatures during summer and winter months, respectively. However, these differences are not seen in the minimum temperatures (Fig. 4c). The minimum temperatures inside and outside are very close to each other for almost every month. According to these results, hotter and cooler conditions form within the doline during the summer and winter periods, respectively.

Another important difference between the inside and outside of the doline was observed in humidity. The average annual humidity inside and outside was 65% and 58%, respectively (Table 2). While humidity is equal during the spring and summer months; the inside displays more humidity than outside during the winter and autumn (Fig. 4d). In terms of daily humidity, it exceeds 90% for 150 days and 122 days on the inside and outside, respectively. This shows that inside the doline is more humid than outside.

Table 2. Monthly climate parameters recorded by dataloggers inside and outside doline.

Months	Average Temp. (°C)		Maximum Temp (°C)		Minimum Temp. (°C)		Max-Min T. Difference (°C)		Average Humidity (%)	
Jan.	-1.1	0.8	6.1	14.7	-8.5	-11.7	14.6	26.4	91	76
Feb.	0.6	3.0	12.3	19.4	-6.9	-7.6	19.2	27	84	69
March	3.6	4.7	19	18.4	-7.9	-7.8	26.9	26.2	67	63
April	7.9	7.6	27.7	23.7	-2.3	-3	30	26.7	69	70
May	17.5	16.9	35.9	33.6	4.2	2.3	31.7	31.3	47	47
June	21.2	20.9	37.5	33.9	11.7	11	25.8	22.9	50	52
July	24.0	23.8	40.4	38.1	13.5	12.7	26.9	25.4	41	41
Aug.	23.2	23.4	38.3	37.2	12.1	11.2	26.2	26	39	38
Sept.	18.9	20.0	36.9	35.3	8.2	7.4	28.7	27.9	43	40
Oct.	10.9	14.0	25.7	28.5	-2.1	-1.2	27.8	29.7	72	59
Nov.	4.6	7.5	14.7	21.4	-6	-5	20.7	26.4	80	66
Dec.	0.8	2.1	8.7	16.7	-10.7	-9.9	19.4	26.6	90	81
Annual	11.0	12.0							65	58

Inside datalogger

Outside datalogger

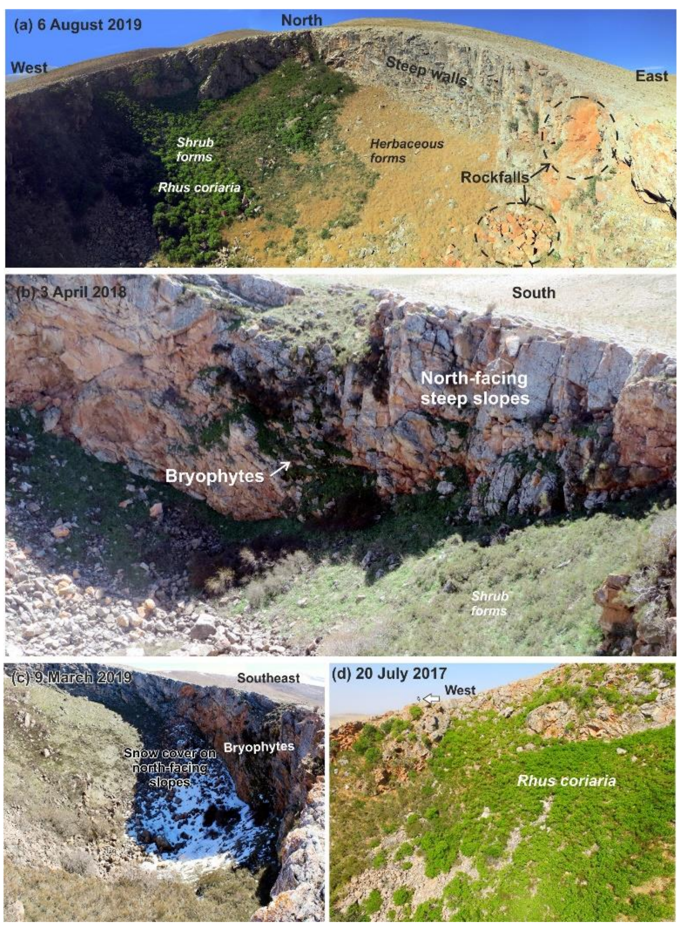

Figure 5. Photographs of study area in different seasons (White arrow in (d) shows human figure for scale).

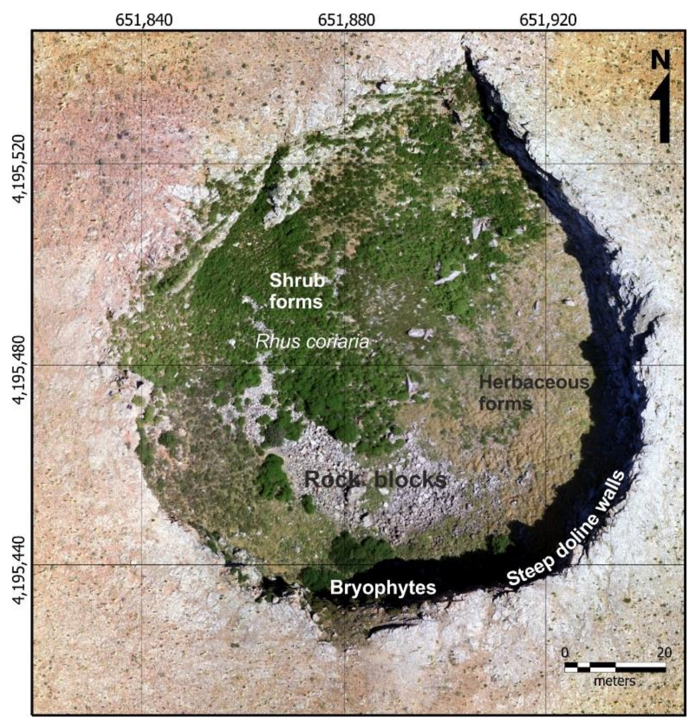

Figure 6. Main ecological areas of doline (UTM, zone 36).

Plant species

Dolines are especially valuable for scientific research and nature conservation due to their microclimatic conditions, geomorphological features, vegetation pattern and species composition (Bátori et al., 2011). The morphologic characteristics of karst depressions strongly determine both the abiotic (e.g., air humidity, air temperature, soil moisture) and biotic (e.g., vegetation pattern) factors of dolines (Batori et al., 2012). The most characteristic topographic features of dolines are their slope and aspect properties. Therefore, spatial variations in slope and aspect are the determinant factors on vegetation pattern, species distribution and ecosystem processes in dolines (Bennie et al., 2008). In many landscapes there are marked differences in the vegetation community and species occurrence between north and south-facing slopes. For example, while north-facing slopes in the study area comprise sciophytes (e.g. *Tortula subulata*), on south-facing slopes are found xerophytes (e.g. *Melica persica*).

From our field studies, a total of 156 plant species were detected in the doline (Table 3). Furthermore, a golden eagle (*Aquila chrysaetos*) was determined nesting and laying her eggs on the steep wall of the doline. During the studied period, this eagle reared two nestlings. A few foxes (*Vulpes vulpes*) were also seen in the doline at various times.

Most of the plant species (152) belonged to the Magnoliophyta family (Table 3). All plant species were collected from rocky and steppe habitat. Steppe vegetation was found in shrub and herbaceous forms. While shrubs clustered on the west side of the doline (east-facing slopes), herbaceous forms were clustered in the east part of the doline (on east-facing slopes) (Fig. 5a). Besides this, the walls on the south side of the doline (north-facing slopes) were covered with bryophytes (Fig. 5b). According to this distribution, three different vegetation regions were observed in the doline: south-facing and east-facing slopes covered with shrubs, west-facing slopes covered with herbaceous plants, and north-facing slopes, especially the steep walls, covered with bryophytes (Figs. 5 and 6).

Rhus coriaria is dominant among the shrub forms (Fig. 5a and d). Other co-dominant shrub forms are *Jasminum fruticans, Rosa pulverulenta, R. canina Cerasus mahaleb* var. *mahaleb, Crataegus orientalis, Pyrus elaeagnifolia, Cotoneaster nummularius,* and *Prunus spinosa.*

Herbaceous forms in the steppe vegetation are *Valeriana dioscoridis, Salvia recognita, S. microstegia, Marrubium astracanicum* subsp. *astracanicum, Artemisia campestris* var. *campestris, Johrenia dichotoma, Urtica dioica* subsp. *dioica, Falcaria falcarioides, F. vulgaris, Astragalus plumosus, A. gummifer, Phlomis nissolii, Alcea biennis*, *Silene chlorifolia, S. spergulifolia, Vicia cracca* subsp. *stenophylla, Centaurea solstitialis* subsp. *solstitialis, C. urvillei* subsp. *armata*, *Pimpinella corymbosa, Melica persica* subsp. *canescens, Poa bulbosa, Avena fatua* var. *fatua, Festuca pratensis, Verbascum orientale* subsp. *brachysepalum*, etc.

Life forms in the rock vegetation are found in shrub and herbaceous forms.

The dominant shrub members in rock vegetation are *Rhus coriaria* and *Ephedra major* subsp. *major.* In addition, *Pyrus elaeagnifolia, Cotoneaster nummularius, Rosa pulverulenta* and *Euphorbia kotschyana* are co-dominant members.

Herbaceous forms in the rock vegetation are *Homalothecium sericeum,* a moss species, *Umbilicus luteus, Rosularia libanotica, Sedum acre* subsp. *acre, Lamium garganicum* subsp. *striatum* var. *striatum*, *Chrysophthalmum* montanum, *Alkanna orientalis* var. *orientalis, Satureja cuneifolia, Chenopodium foliosum, Achillea teretifolia, Paronychia cephalotes* var. *cephalotes, Valeriana dioscoridis, Galium incanum* subsp. *elatius, Galium aparine, Saxifraga tridactylites*, etc.

In addition, some plants in both the rock and steppe vegetation are geophytes. These geophytes are *Valeriana dioscoridis, Gagea villosa* var. *villosa, Allium atroviolaceum, Allium flavum* subsp. *tauricum* var. *tauricum, Allium scorodoprasum* subsp. *rotundum*, *Muscari bourgaei, M. neglectum, Asphodeline prismatocarpa, Ornithogalum narbonense, Colchicum triphyllum, Arum rupicola* var. *rupicola* and *Geranium tuberosum.*

Endemic plants found within the doline are *Pterocephalus pinardii, Arum rupicola* var. *rupicola, Muscari bourgaei, Centaurea kotschyi* var. *kotschyi, Achillea teretifolia, Gundelia tournefortii* var. *armata, Cousinia olivieri, Phryna ortegioides, Astragalus mesogitanus, Astragalus condensatus, Ebenus laguroides, Phlomis nissolii, Salvia absconditiflora, S. recognita, Verbascum orientale* subsp. *brachysepalum*, *Asphodeline prismatocarpa* and *Viola heldreichiana.*

Table 3. List of plant species in the doline (*: endemic).

Taxa		Phytogeographic element
(a) Bryophyta		
Brachytheciaceae		
1	*Homalothecium sericeum* (Hedw.) Schimp.	
Pottiaceae		
2	*Tortula subulata* Hedw.	
(b) Pteridophyta		
Aspleniaceae		
1	*Asplenium ceterach* L.	
(c) Spermatophyta		
(c1) Pinophyta		
Ephedraceae		
1	*Ephedra major* Host. subsp. *major*	
(c2) Magnoliophyta		
Amaranthaceae		
1	*Chenopodium foliosum* (Moench) Asch.	
Amaryllidaceae		
2	*Allium atroviolaceum* Boiss.	
3	*Allium flavum* L. subsp. *tauricum* var. *tauricum* (Besser ex Rchb.) Stearn	Mediterranean
4	*Allium scorodoprasum* L. subsp. *rotundum* (L.) Stearn	
Anacardiaceae		
5	*Rhus coriaria* L.	
Apiaceae		
6	*Pimpinella corymbosa* Boiss.	Irano-Turanian
7	*Johrenia dichotoma* DC.	Irano-Turanian
8	*Turgenia latifolia* (L.) Hoffm.	
9	**Pterocephalus pinardii* Boiss.	East Mediterranean
10	*Pastinaca sativa* L. subsp. *urens* (Req. ex Gren. & Godr.) Celak.	
11	*Eryngium campestre* L.	
12	*Falcaria falcarioides* (Bornm. & H.Wolff) H.Wolff	
13	*Falcaria vulgaris* Bernh.	
Apocynaceae		
14	*Vincetoxicum tmoleum* Boiss.	Irano-Turanian
Araceae		
15	**Arum rupicola* Boiss. var. *rupicola*	Irano-Turanian
Asparagaceae		
16	**Muscari bourgaei* Baker	Mediterranean
17	*Muscari neglectum* Guss. ex Ten.	
18	*Ornithogalum narbonense* L.	
Asteraceae		
19	*Senecio vernalis* Waldst. & Kit.	
20	*Senecio pseudo-orientalis* Schischk.	Irano-Turanian
21	*Lactuca orientalis* (Boiss.) Boiss.	Irano-Turanian
22	*Lactuca serriola* L.	

23	*Centaurea virgata* Lam.	Irano-Turanian
24	**Centaurea kotschyi* (Boiss. & Heldr.) Hayek var. *kotschyi*	
25	*Centaurea solstitialis* L. subsp. *solstitialis*	
26	*Centaurea urvillei* DC. subsp. *armata* Wagenitz	East Mediterranean
27	*Carlina oligocephala* Boiss. & Kotschy	
28	*Echinops spinosissimus* Turra subsp. *bithynicus* (Boiss.) Greuter	Irano-Turanian
29	*Anthemis arvensis* L.	
30	*Crepis foetida* L. subsp. *rhoeadifolia* (M.Bieb.) Celak.	
31	*Crepis micrantha* Czerep.	
32	*Picris strigosa* M.Bieb. subsp. *strigosa*	Irano-Turanian
33	**Achillea teretifolia* Willd.	Irano-Turanian
34	*Picnomon acarna* (L.) Cass.	Mediterranean
35	*Chondrilla juncea* L.	
36	*Carduus pycnocephalus* L. subsp. *albidus* (M. Bieb.) Kazmi	
37	*Filago arvensis* L.	
38	*Gundelia tournefortii* L. var. *armata* Freyn & Sint., Endemic	Irano-Turanian
39	*Artemisia alpina* Pall. ex Willd.	
40	*Bombycilaena erecta* (L.) Smoljan.	
41	*Anthemis pseudocotula* Boiss.	
42	*Crupina crupinastrum* (Moris) Vis.	
43	**Cousinia olivieri* DC.	Irano-Turanian
44	*Artemisia campestris* L. var. *campestris*	
45	*Echinops ritro* L.	
46	*Chrysophthalmum montanum* (DC.) Boiss.	Irano-Turanian
Boraginaceae		
47	*Alkanna orientalis* (L.) Boiss. *var. orientalis*	Euro-Siberian
48	*Phyllocara aucheri* (A.DC.) Guşul.	
49	*Asperugo procumbens* L.	
Brassicaceae		
50	*Alliaria petiolata* (M.Bieb.) Cavara & Grande	
51	*Arabis aucheri Boiss.*	
52	*Alyssum strigosum* Banks & Sol.subsp. *strigosum*	
53	*Draba nuda* (Bélanger) Al-Shehbaz & M.Koch	
54	*Conringia clavata* Boiss.	
55	*Microthlaspi perfoliatum* (L.) F.K.Mey.	
Caprifoliaceae		
56	*Scabiosa rotata* M.Bieb.	
57	*Scabiosa argentea* L.	
58	*Valeriana dioscoridis* Sm.	East Mediterranean
59	*Morina persica* L. var. *persica*	Irano-Turanian
Caryophyllaceae		
60	*Arenaria serpyllifolia* L.	

61	*Dianthus zonatus* Fenzl var. *zonatus*	
62	*Dianthus crinitus Sm. var. crinitus*	
63	*Paronychia cephalotes* var. *cephalotes* (M. Bieb.) Bess.	
64	*Paronychia argentea* Lam. var. *argentea*	Mediterranean
65	**Phryna ortegioides* (Fisch. & C.A. Mey.) Pax & K. Hoffm.	Irano-Turanian
66	*Silene argentea* Ledeb.	Irano-Turanian
67	*Silene chlorifolia* Sm.	Irano-Turanian
68	*Silene spergulifolia* (Desf.) M.Bieb.	Irano-Turanian
69	*Silene stenobotrys* Boiss. & Hausskn.	Irano-Turanian
70	*Silene subconica* Friv.	
71	*Velezia rigida* L.	
Cistaceae		
72	*Helianthemum salicifolium* (L.) Mill.	
Colchicaceae		
73	*Colchicum triphyllum* Kunze	Mediterranean
Convolvulaceae		
74	*Cuscuta europaea* L.	
Crassulaceae		
75	*Sedum acre* L. subsp. *acre*	
76	*Umbilicus luteus* (Huds.) Webb & Berthel.	
77	*Rosularia libanotica* (Strand ex L.) Samuelsson	East Mediterranean
Euphorbiaceae		
78	*Euphorbia kotschyana* Fenzl	
79	*Euphorbia denticulata* Lam.	Irano-Turanian
80	*Euphorbia macroclada* Boiss.	
Fabaceae		
81	*Astragalus plumosus* Willd.	Irano-Turanian
82	**Astragalus mesogitanus* Boiss.	Irano-Turanian
83	**Astragalus condensatus* Ledeb.	Irano-Turanian
84	*Astragalus gummifer* Labill.	
85	**Ebenus laguroides* Boiss.	Irano-Turanian
86	*Pisum sativum* L. subsp. *sativum* var. *sativum*	
87	*Medicago radiata* L.	Irano-Turanian
88	*Medicago monantha* (C.A. Mey.) Trautv.	Irano-Turanian
89	*Vicia cracca* L. subsp. *stenophylla* Vel.	
Geraniaceae		
90	*Erodium acaule* (L.) Becherer & Thell.	Mediterranean
91	*Geranium rotundifolium* L.	
92	*Geranium pyrenaicum* Burm.	
93	*Geranium tuberosum* L.	
Hypericaceae		
94	*Hypericum scabrum* L.	Irano-Turanian
Lamiaceae		
95	**Phlomis nissolii* L.	Irano-Turanian
96	*Phlomis pungens* Willd. var. *pungens*	

97	*Teucrium polium* L. subsp. *polium*	
98	*Teucrium chamaedrys* L. subsp. *chamaedrys*	
99	*Satureja cuneifolia* Ten.	Mediterranean
100	**Salvia absconditiflora* (Montbret & Aucher ex Benth.) Greuter & Burdet	Irano-Turanian
101	**Salvia recognita* Fisch. & C.A. Mey.	Irano-Turanian
102	*Salvia microstegia* Boiss. & Balansa	Irano-Turanian
103	*Salvia candidissima* Vahl subsp. *candidissima*	
104	*Stachys annua* (L.) L. subsp. *annua* var. *annua*	
105	*Marrubium astracanicum* Jacq. subsp. *astracanicum*	
106	*Lallemantia iberica* (M.Bieb.) Fisch. & C.A.Mey.	Irano-Turanian
107	*Lamium garganicum* L. subsp. *striatum* (Sm.) Hayek var. *striatum*	
108	*Lamium amplexicaule* L. var. *amplexicaule*	
109	*Clinopodium graveolens* (M.Bieb.) Kuntze subsp. *graveolens*	
110	*Marrubium parviflorum* Fisch. & C.A.Mey. subsp. *parviflorum*	
111	*Sideritis montana* L. subsp. *montana*	
112	*Stachys woronowii* (Schischk. ex Grossh.) R.R.Miller	Irano-Turanian
113	*Gagea villosa* (M.Bieb.) Sweet var. *villosa*	Mediterranean
Malvaceae		
114	*Alcea biennis* Winterl	
Oleaceae		
115	*Jasminum fruticans* L.	Mediterranean
Papaveraceae		
116	*Papaver rhoeas* L.	
117	*Papaver dubium* L. subsp. *dubium*	
118	*Fumaria parviflora* Lam.	
Plantaginaceae		
119	*Veronica praecox* All.	
Plumbaginaceae		
120	*Acantholimon acerosum* (Willd.) Boiss. subsp. *acerosum* var. *acerosum*	
121	*Acantholimon ulicinum* (Wild. Ex Schultes) Boiss. var. *creticum* (Boiss.) Bokhari & Edmondson	
122	*Plumbago europaea* L.	Euro-Siberian
Poaceae		
123	*Aegilops caudata* L.	
124	*Elymus elongatus* (Host) Runemark subsp. *turcicus* (McGuire) Melderis	
125	*Secale montanum* Guss.	
126	*Melica persica* Kunth subsp. *canescens* (Regel) P.H. Davis	Irano-Turanian
127	*Poa bulbosa* L.	
128	*Poa pratensis* L.	
129	*Avena fatua* L. var. *fatua*	
130	*Stipa holosericea* Trin.	Irano-Turanian
131	*Stipa arabica* Trin. & Rupr.	
132	*Festuca pratensis* Huds.	

Ranunculaceae		
133	*Nigella arvensis* L.	
134	*Delphinium venulosum* Boiss.	Irano-Turanian
Rosaceae		
135	*Cotoneaster nummularius* Fisch. & C.A. Mey.	
136	*Crataegus orientalis* Pall. ex M.Bieb. subsp. *szovitsii* (Pojark.) K.I. Chr.	Irano-Turanian
137	*Rosa pulverulenta* M. Bieb.	
138	*Rosa canina* L.	
139	*Pyrus elaeagnifolia* Pall. subsp. *elaeagnifolia*	
140	*Cerasus mahaleb* (L.) Mill. var. *mahaleb*	
141	*Prunus spinosa* L.	
142	*Geum heterocarpum* Boiss.	
143	*Galium incanum* Sm. subsp. *elatius* (Boiss.) Ehrend	Irano-Turanian
144	*Galium aparine* L.	
145	*Galium verticillatum* Danthoine ex Lam.	
146	*Cruciata taurica* (Pall. ex Willd.) Ehrend.	Irano-Turanian
Saxifragaceae		
147	*Saxifraga tridactylites* L.	Mediterranean
Scrophulariaceae		
148	**Verbascum orientale* (L.) All. subsp. *brachysepalum* (Fisch. & Trautv.) Karavel. & Aytaç	East Mediterranean
149	*Verbascum cheiranthifolium* Boiss. var. *cheiranthifolium*	
Xanthorrhoeaceae		
150	**Asphodeline prismatocarpa* J.Gay ex Boiss.	East Mediterranean
Urticaceae		
151	*Urtica dioica* L. subsp. *dioica*	Euro-Siberian
Violaceae		
152	**Viola heldreichiana* Boiss.	Mediterranean

The rate of cosmopolitan plant types that are not subdivided are is uttermost. According to phytogeographic classification, due to the location of the study area, Irano-Turanian elements are dominated in doline. After that, Mediterranean, East Mediterranean, and Euro-Siberian elements follow, respectively (Table 4).

Table 4. The distribution of phytogeographic elements

Phytogeographic element	Number of species	Ratio (%)
Irano-Turanian	39	24.8%
Mediterranean	10	6.4%
East Mediterranean	6	3.8%
Euro-Siberian	3	1.9%
Cosmopolitan	99	63.1%

Conclusion

Topographic characteristics and microclimatic features considerably impact the number and distribution of plant species in dolines. At mid to high latitudes, the slope and aspect of the ground alters the amount of solar radiation received by the surface and can be an important factor in determining the microclimate and ecological conditions in the doline. For this reason, different aspects and slopes exhibit differing vegetation cover due to microclimatic variations and the resulting ecological diversity. In this study, habitats were determined using field observation, microclimate analyses and a UAV surface model to examine a collapse doline located on the steppes of Central Anatolia. According to our results, while the doline is filled with cold and humid air during winter, it is filled by warm air during the summer months. The coldest and wettest part of the doline is the steep north-facing walls which are covered with bryophytes. The north-facing slopes are also covered with hygrophilous plants since the north-facing walls and slopes are in shadow for much of the year. The other slopes do not have a unique vegetation cover. While the south and east-facing slopes are covered with shrub forms, the west-facing slopes are covered with herbaceous forms. These differences result from variations in daily temperature and humidity. But for these result, we need climate observation on south, east and west-facing slopes.

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