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Environmental Factors and Semiarid Plants Species on Eroded Marly Soils in Southwest Anatolia (Eskişehir/Türkiye)

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ABSTRACT

The natural regeneration of vegetation in areas of marly soils is restricted due to drought and soil erosion. For the ecological restoration of eroded areas, the selection of suitable plant species is critical. The aim of this study is to assess specific plant species and their ecological characteristics for their ability to thrive under drought in eroded areas with marly soil. The study was conducted on 36 sampling locations in the marly areas of Eskisehir-Bozan, Türkiye, during the most drought-prone months, August and September, in 2011 and 2012. Vegetation sampling was conducted according to the Braun-Blanquet method. Fifteen plant taxa with the highest coverage and frequency were identified. Relationships between plant species and environmental factors were determined using Spearman's correlation analysis. According to the results of numerical analysis, there were correlations between ecological parameters including nitrogen, phosphorus, organic matter, lime, slope, altitude and plant taxa. The resistance rate of fifteen plant taxa in marly areas is quite high even in the driest months. These plant taxa, possessing properties essential for soil protection, may be used for revegetation practices of marly areas exposed to soil erosion. This study's findings will provide useful guidance for vegetation programs.

Keywords: Eroded area, Growth form, Vegetation, Spearman's correlation

1. Introduction

Marl rocks are widespread in many countries and marl derived soil is a mixture of clay and calcium carbonate and is very susceptible to erosion (Bouma & Imeson 2000; Sokouti & Razaki 2015). It has been determined that the source of sediment yield in arid areas is marly soils with high erodibility (Thoms et al. 2004). Steep slopes and low vegetation lead to further erosion. Soil erosion affects all natural and cultivated areas around the world and causes significant soil loss (Burylo et al. 2011) and is known to be significant threat to sustainability in the context of ecosystem services. In particular, it is primarily responsible for land degradation in the cultivated areas located in fragile ecosystems (FAO & ITPS 2015). There is a consensus that ecosystem restoration should be scientifically reliable and reflect an accurate understanding of ecological principles (Stokes et al. 2014). Data regarding vegetation dynamics and some ecological characteristics of an area can help us assess the vulnerability of degraded soils due to soil erosion and the effectiveness of restoration activities (Burylo et al. 2011). In Türkiye, water erosion is a major problem and the predicted average soil loss rate is higher than 5 t ha-1 y-1 in the 26.4% of agricultural lands (Erpul et al. 2020). In particular in the wheat production areas, which constitute 67% of the agricultural areas in which field crops are cultivated, it leads to a significant reduction in production potentials at the national scale. But, wheat demand tends to increase due to rising population density (Anonymous 2019). Therefore, accurate estimation of land productivity under the accelerated soil erosion dynamics has great importance in terms of conservation natural resources (Saygın 2021).

The Central Anatolian Region of Türkiye is a mountainous Mediterranean climate, and semiarid climatic conditions prevail in this region (Akman 1999). The main anthropogenic pressures affecting the forest resources in this region are overexploitation and overgrazing (Kahveci 2017). Relict forests are essential for ecological restoration in such degraded semiarid regions (Kahveci 1998). The Anatolian black pine woodlands in the marl areas of Eskişehir on the eastern foot slopes of the Sündiken Mountains are one of the relict forests. In addition, plants in these areas can be evaluated as seed source reserves for plant species used in revegetation efforts. The plants in these areas can adapt to changing environmental conditions (Loreau et al. 2001).

Vegetation degradation leads to soil erosion that decline in vegetation cover and floristic composition (Guerrero-Campo & Montserrat-Martí 2000), and water erosion and drought conditions in marly fields prevent the regeneration of vegetation (Cerda 1999; Breton et al. 2016). The relationships between soil erosion on marly soils and the plant or vegetation characteristics have been widely studied (Cerda 1999; Guerrero-Campo & Montserrat-Martí 2000; Guerrero-Campo & Montserrat-Martí 2004; Guerrero-Campo et al. 2008; De Baets et al. 2007; Burylo et al. 2009; Varavipour et al. 2010; Burylo et al. 2011; Breton et al. 2016). Ecological studies have indicated that it is crucial to understand the environmental conditions and past rehabilitation projects to minimise erosion in marly soils. The selection of suitable species in studies of ecological restoration is also critical (Bochet & García-Fayos 2004; Bochet & García-Fayos 2015). Plant studies in the marly areas in Türkiye have to date generally focused on plant communities (Çetik 1985; Akman 1995). These vegetation studies are insufficient to reveal relevant site factors in detail. The aim of this study is to determine the plant species and some properties of eroded extremely limy soils in semiarid land, and to record growth forms of the plant species. This assessment will allow, for the first time, a determination of the plant species that can be used in the revegetation practices of highly limy and alkaline (marly) soils in semiarid areas.

2. Material and Methods

2.1. Site descriptions

This study was conducted in areas surrounding Bozan, Eskisehir, Türkiye (Table 1), in areas of degraded Anatolian black pine (*Pinus nigra* J.F.Arnold subsp. *pallasiana* (Lamb.) Holmboe) and anthropogenically degraded oak-juniper and steppe that developed after forest destruction in the eastern foot slopes of the Sündiken Mountains. It is in the Irano-Turanian phytogeographical region (Davis 1965). Vegetation cover has been destroyed due to long-term animal grazing pressure (Figure 1), which has resulted in soil and water erosion and the destruction of the areas vegetation. Marly soils are common and dominant in the research area. Generally, the upper soil layer in the area is lost because of erosion. As a result, surface erosion is generally observed in the area.

Table 1- Sampling areas, habitat and environmental variables

Sampling location	*Date*	*Locality*	*Latitude (36S)*	*Longitude*	*Sampling location*	*Date*	*Locality*	*Latitude (36S)*	*Longitude*
1	05.07.2011	Bozan-Circir	339327	4410312	**19**	10.07.2012	Circir-Agachisar V. road	339935	4412696
2	05.07.2011	Bozan-Circir	339328	4410226	**20**	10.07.2012	Circir-Agachisar V. road	339810	4412499
3	02.09.2011	Northern of Bugduz V.	337487	4418965	**21**	25.06.2015	4 km to Tasliburun wood storage	339589	4415712
4	02.09.2011	Southern of Ozdenk V.	329683	4417670	**22**	11.07.2012	Easthern of Bugduz V.	336555	4414325
5	02.09.2011	Southern of Ozdenk V.	329722	4417795	**23**	11.07.2012	Bugduz V.	337203	4415574
6	03.09.2011	Southern of Ozdenk V.	330057	4418877	**24**	11.07.2012	Bugduz V.	337030	4417567
7	03.09.2011	Southern of Ozdenk V.	330099	4417911	**25**	26.06.2015	Eastern of Derekoy V.	330126	4420066
8	03.09.2011	Bozan-Mihaliccik 4. km	340789	4409553	**26**	12.07.2012	Bozan-Mihaliccik road	346325	4410578
9	03.09.2011	Eastern part of Asagi Dudas V.	349093	4408892	**27**	12.07.2012	Asagi Dudas V.	348970	4408772
10	03.09.2011	Bozan-Circir	339904	4411838	**28**	12.07.2012	Asagi Dudas V.	348474	4408399
11	04.09.2011	Southeastern of A.Doganoglu V.	344636	4411530	**29**	12.07.2012	İlme farm	343095	4408100
12	04.09.2011	2 km east of Karageyikli V.	352529	4411977	**30**	12.07.2012	Southern of Asagi Doganoglu V.	346482	4408847
13	04.09.2011	2 km east of Karageyikli V.	352593	4411967	**31**	12.07.2012	Yukari Doganoglu V.	346888	4409057
14	04.09.2011	2 km east of Karageyikli V.	352593	4411967	**32**	13.07.2012	Between Ozdenk-Cukurhisar V.	330410	4416942
15	09.07.2012	Tasliburun wood storage	339876	4419335	**33**	13.07.2012	Between Agachisar-Ozdenk V.	330485	4417530
16	09.07.2012	Tasliburun	339664	4418684	**34**	13.07.2012	Circir	340901	4411107
17	09.07.2012	Between Circir-Tasliburun	339873	4414055	**35**	13.07.2012	Agachisar V. road	339540	4415828
18	09.07.2012	Tasliburun-Kalınagil	339469	4418790	**36**	20.05.2015	Ozdenk V.	330157	4418041

V: Village

Figure 1- Animal grazing pressure in the study area

2.2. Climate of the study area

We used climatic data from meteorological stations in the Eskisehir-Region (1960–2015) and Alpu-Region (1984–2002) taken from the Meteorology General Directorate which were the stations closest to the study area. The data were evaluated according to the Emberger method (Akman & Daget 1971; Akman 1999). Based on these data from the weather stations, the Eskişehir region is located in a semiarid and cold winter Mediterranean bioclimate and the Alpu region is located in a semiarid and extremely cold winter Mediterranean bioclimate (Table 2). The precipitation regime of the Alpu and Eskisehir stations is respectively spring, winter, autumn, and summer with the least precipitation in the summer season. According to the precipitation-temperature graph (Walter & Lieth 1967), there is a dry period from June to October in the study area (Figure 2).

Table 2- Bioclimatic classification of the research area

Meteorological station		*P*	*M*	*m*	*PE*	*Q*	*S*	*Bioclimate type*
Locality	*Alt. (m)*							
Alpu-Region	765	376.8	30.4	-4.2	53.7	38.04	1.77	Semi-arid, extremely cold winter Mediterranean bioclimate
Eskişehir-Region	801	286.0	29.1	-3.0	44.0	31.13	1.51	Semi-arid, cold winter Mediterranean bioclimate

P: Average annual precipitation total (mm); M: Maximum temperature average of the warmest month (°C); m: Minimum temperature average of the coldest month (°C); PE: Sum of summer precipitation (mm); S: Drought index = PE/M; Q: Precipitation-temperature equal = $\frac{2000P}{(M+m+546.4)(M-m)}$

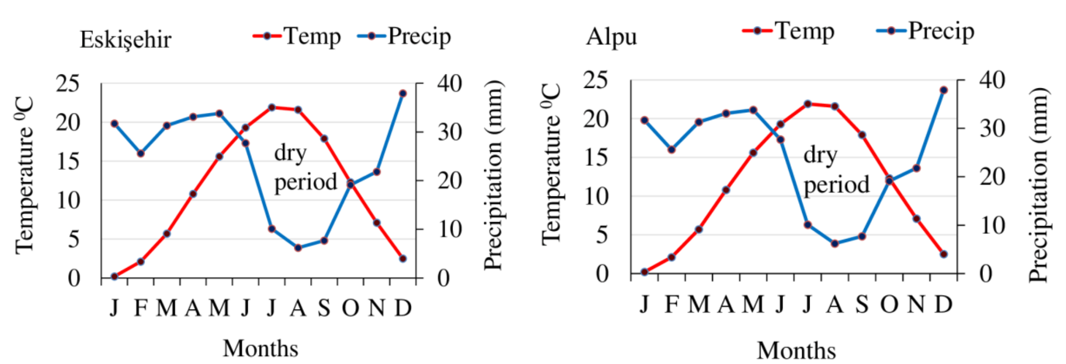

Figure 2- Climate diagrams of the nearest meteorological stations from the study area

2.2. Data collection and methods

The taxa studied were collected from 36 different locations where erosion had been observed. The sampling areas were within degraded forests, shrublands, and steppe areas (Figure 3). The size of the sampling areas is according to the smallest area method, which is 200 m^2 in wooded and bushy areas and 50 m^2 in steppe vegetation (Akman et al. 2001).

Figure 3- Degraded forest (a), shrublands (b), and steppe areas (c)

The study area is under intense anthropogenic pressure. However, the sampling areas were selected so that the vegetation was as representative as possible. The studies were carried out in August and September when the drought was most severe in 2011–2012, and all vascular plants were recorded on vegetation scorecards. The Braun-Blanquet (1932) method was used for vegetation measurements. Physiographic factors such as slope (degree), exposure (degree) and elevation (m) were determined. For the purpose of determine soil properties of each sampling area, 72 soil samples were taken from the depth of 0–10 cm and 10–30 cm. Growth forms of plant species were also recorded. The high-frequency species were determined by the vegetation table. Following this, plant species that formed bunches and colonies, shrubs and plants in tree form were identified.

2.3. Laboratory analyses

The collected plant specimens were identified according to Davis (1965–1985). Soil samples brought to the lab for analysis were air-dried, ground and sifted through a 2-mm sieve. Physical soil analyses included texture [sand (%), silt (%) and clay (%)], and chemical soil analyses included soil pH, organic matter (%) lime ($CaCO_3$, %), total nitrogen (%) and available phosphorus (P, ppm). Soil pH was determined using an electrometric method in a solution ratio of 1:5 (soil/water) in distilled water (TS ISO 10390 2013). The texture was measured using the Bouyoucos hydrometer method (Kroetsch & Wang 2008). Total lime ($CaCO_3$) and nitrogen were determined by Scheibler calcimeter (Kacar 2009) and the Kjeldahl method (Jackson 1962), respectively. Organic matter content was determined using the Walkley–Black wet oxidation method (TS 8336 2008). Available phosphorus in alkaline soils was measured using the Olsen method (Kacar 2009).

2.4. Statistical analysis

In the statistical analysis, the presence/absence (1/0) data of plant species and numerical data of environmental variables were evaluated. Relationships between environmental factors and plant taxa were calculated using Spearman's correlation coefficient from non-parametric tests in SPSS program, because the data were not normally distributed.

3. Results and Discussion

In marly areas, different forms of soil erosion, are one of the prominent features (Thoms et al. 2004). Land erosion is clearly seen in the marl soils that are the subject of the study. For the purpose of reduce soil erosion, the soil loss preventive clonal and ligneous plant species could be used in planting studies in marl areas.

The plant taxa with the highest frequency and the growth forms were as follows (frequency of plant taxa are given in parentheses):

3.1. Bunched plants

Festuca valesiaca Schleich. ex Gaudin (26), *F. callieri* (Hack.) Markgr. subsp. *callieri* (14) and *Bromus tomentellus* Boiss. (29).

3.2. Batch plants (clonal plants)

Alyssum sibiricum Willd. (27), *Convolvulus phrygius* Bornm. (27, **endemic**), *Thymus leucostomus* Hausskn & Velen. (30, **endemic**), *Globularia orientalis* L. (22).

3.3. Chamaephyte and shrub

Salvia tchihatcheffii (Fisch. & C.A.Mey.) Boiss. (17, **endemic**), *Genista aucheri* Boiss. (16, **endemic**), *Jasminum fruticans* L. (11), *Rhamnus thymifolia* Bornm. (18, **endemic**), *Berberis crataegina* DC. (28), *Juniperus oxycedrus* L. subsp. o*xycedrus* (34) and *Quercus pubescens* Willd. (24).

3.4. Small tree and tree species

Quercus pubescens and *Pinus nigra* subsp. *pallasiana* (16).

The majority of these plant species, which are frequently seen in the study area, have a strong life energy even in the driest season. Notable among these species are: *Festuca* sp., *Convolvulus phrygius*, *Genista aucheri*, shrub and tree species.
The results for some physiographic variables of the study area were presented in Table 3.

All identified plant taxa in this study were within the area formed by marly soil. All examined taxa demonstrated a natural distribution on both sunny and shady aspects. The altitude of the study area is between 860 and 1125 meters with steep slopes (Table 3).

Table 3- Environmental factors of the study area

Sampling location	*Altitude (m)*	*Exposure (°)*	*Slope (°)*	*Bedrock*	*Sampling location*	*Altitude (m)*	*Exposure (°)*	*Slope (°)*	*Bedrock*
1	870	270	30	Marl	**19**	927	270	45	Marl
2	898	270	47	Marl	**20**	928	90	37	Marl
3	996	115	55	Chlorite schist	**21**	1047	90	3	Marl
4	946	135	15	Marl	**22**	905	90	10	Marl
5	959	135	10	Marl	**23**	917	315	37	Limestone
6	1026	225	30	Limestone	**24**	965	90	25	Limestone
7	1023	315	30	Limestone	**25**	966	270	50	Claystone
8	863	180	30	Marl	**26**	902	270	30	Marl
9	932	20	22	Marl	**27**	936	45	23	Limestone
10	938	200	35	Marl	**28**	957	315	13	Marl
11	904	110	35	Limestone	**29**	901	200	28	Marl
12	979	20	3	Marl	**30**	940	90	16	Marl
13	980	270	20	Marl	**31**	925	135	28	Marl
14	976	90	22	Marl	**32**	968	200	37	Limestone
15	1123	270	40	Marble	**33**	987	270	25	Limestone
16	1086	270	8	Marl	**34**	880	270	30	Limestone
17	991	270	30	Marl	**35**	1030	70	4	Marl
18	1046	45	20	Claystone	**36**	1022	250	28	Marl

When considering the soil characteristics of the species, it can be seen that the soil texture of the study area is clay on the marl, on different bedrocks, is sometimes clayey loam and rarely sandy. All plants were generally distributed on soils that had high pH and lime levels. The soils were moderately and strongly alkaline (Table 4). The lime content in the soil is greater than 25%, except for areas with chlorite-schist and claystone bedrock. The plants can be grown in soils with extremely high lime conditions. The quantity of organic matter, N, and P were found to be 0.27–5.88 %, 0.04–0.31 % and 5–70 ppm, respectively (Table 4).

Table 4- The chemical properties of soils and soil texture

Sampling location	*Lime_1*	*Lime_2*	*pH_1*	*pH_2*	*OM_1*	*OM_2*	*N_1*	*N_2*	*P_1*	*P_2*	*Soil texture (0-10 cm)*	*Soil texture (10-30 cm)*
1	42.43	46.89	7.84	7.84	3.58	2.10	0.25	0.16	20	12	Clayey	Clayey
2	35.04	38.75	7.86	8.02	3.26	1.54	0.23	0.12	19	10	Clayey	Clayey
3	6.08	2.12	8.44	8.55	0.43	0.27	0.05	0.04	10	7	Clayey	Clayey
4	39.52	32.18	8.34	8.32	1.99	1.52	0.13	0.13	12	10	Clayey	Clayey
5	39.97	47.54	8.37	8.54	1.68	0.91	0.13	0.08	11	9	C. loam	Clayey
6	25.16	22.71	8.42	8.56	1.23	0.76	0.10	0.06	11	9	Clayey	Clayey
7	25.21	15.07	8.48	8.55	0.96	0.97	0.07	0.05	10	9	Clayey	Clayey
8	50.11	51.55	8.17	8.24	1.99	2.06	0.13	0.14	13	13	Clayey	Clayey
9	65.76	88.72	8.41	8.57	3.25	1.90	0.20	0.11	16	12	C. loam	C. loam
10	79.32	87.83	8.89	9.05	1.38	0.70	0.09	0.06	9	7	Clayey	Clayey
11	75.22	81.37	8.74	8.83	2.76	1.78	0.15	0.09	19	14	Loamy	Loamy
12	79.24	90.77	8.59	9.05	1.70	0.80	0.10	0.05	11	7	Clayey	Clayey
13	63.58	65.59	8.48	8.83	2.22	1.30	0.13	0.07	14	9	Clayey	Clayey
14	78.69	78.15	8.66	8.43	0.62	0.47	0.04	0.04	7	5	Clayey	Clayey
15	31.40	47.67	8.51	8.50	2.72	1.07	0.13	0.06	22	11	Clayey	Clayey
16	32.22	46.76	8.18	8.48	4.19	1.52	0.18	0.08	24	12	Clayey	Clayey
17	65.37	74.83	8.38	8.83	2.27	0.89	0.14	0.07	18	7	Clayey	Clayey
18	6.32	13.62	8.13	8.32	3.25	0.83	0.19	0.08	20	9	Clayey	Clayey
19	78.83	84.32	8.81	9.01	0.98	0.93	0.06	0.05	9	9	Clayey	Clayey
20	49.40	51.25	8.54	8.46	3.47	3.49	0.20	0.20	20	19	Clayey	Clayey
21	34.93	43.44	8.31	8.28	5.77	2.73	0.25	0.16	32	18	C. loam	C. loam
22	59.65	71.35	8.29	8.44	2.22	1.00	0.15	0.08	15	10	Clayey	Clayey
23	50.68	55.65	8.47	8.45	2.06	0.90	0.09	0.06	13	10	Clayey	Clayey
24	27.73	27.11	8.72	8.42	1.91	0.81	0.14	0.08	15	10	Clayey	Clayey
25	12.87	4.44	8.67	8.64	0.64	0.41	0.07	0.05	12	8	Clayey	Clayey
26	79.47	86.79	8.62	8.87	1.10	0.55	0.08	0.05	14	8	Clayey	Clayey
27	49.63	68.04	8.31	8.32	3.92	2.72	0.30	0.19	19	16	C. loam	Clayey
28	31.19	38.36	7.75	7.96	4.81	3.76	0.31	0.25	21	16	C. loam	Clayey
29	34.17	30.88	7.94	8.18	2.54	5.88	0.16	0.31	19	70	C. loam	S.C. loam
30	90.18	90.33	8.78	8.79	0.44	0.44	0.04	0.03	8	8	Clayey	Clayey
31	74.38	72.12	8.53	8.65	1.32	0.68	0.09	0.05	8	7	Clayey	Clayey
32	35.35	37.24	8.42	8.43	0.66	0.65	0.07	0.06	9	8	Clayey	Clayey
33	33.06	35.29	8.39	8.41	1.87	1.20	0.12	0.09	11	8	Clayey	Clayey
34	51.43	40.24	8.38	8.11	2.50	1.74	0.16	0.13	16	9	Clayey	Clayey
35	8.53	34.58	8.28	8.18	3.85	2.78	0.28	0.16	18	11	Clayey	Clayey
36	69.69	60.89	8.65	8.67	0.46	0.47	0.04	0.04	6	5	Clayey	Clayey

1: 0-10 cm; 2: 10-30 cm; Lime (%); pH: Potential of Hydrogen; OM: Organic matter (%); N: Nitrogen (%); P: Phosphorus (ppm); C: Clayey; S: Sandy

The statistical analysis revealed that N, P and soil organic matter were the significant environmental variables associated with the plant taxa (Table 5). There was no significant correlation between lime content at 0-10 cm soil depth, exposure, pH and plant species. *J. oxycedrus* and *F. valesiaca* were positively correlated with N, P and organic matter in soil ($P<0.05$). *Quercus pubescens* preferred soil in which the phosphorus was higher. The positive variables were N and OM, and P at a depth of 10–30 cm for *G. orientalis*. While *J. fruticans* preferred steeper slopes, *G. orientalis* was located on the side with only a slight slope. Compared to the other species in this study, *G. aucheri* preferred relatively lower lime, P and OM. At depths of 0–10 cm, *C. phrygius* presence was negatively correlated with N, P, and organic matter. *R. thymifolia* was negatively correlated with the amount of lime at 10–30 cm soil dept and elevation. Compared to other taxa, *J. oxycedrus*, *G. orientalis* and *F. valesiaca* preferred soils containing more organic matter, and *J. oxycedrus*, *Q. pubescens*, *G. orientalis* and *F. valesiaca* preferred soils containing higher P. No correlation was found between the remaining 7 taxa (*P. nigra* subsp. *pallasiana*, *A. sibiricum*, *T. leucostomus*, *F. callieri*, *B. tomentellus*, *S. tchihatcheffii* and *B. crataegina*) and their site factors. It can be said that ecological tolerance of these taxa is slightly wider considering the ecological conditions of the study area.

Soil erosion control studies are very difficult to conduct in areas with high anthropogenic impact and extreme site conditions. Water deficiency is the most important factor affecting plant development in semiarid climates. The increase in rainfall and decrease in temperature that occurs with altitude increase in this region positively affects the water economy (Kahveci 1998; Güner et al. 2016). This elevation limit was determined to be 1000–1200 m in black pine plantations in the Central Anatolia region (Güner et al. 2016). The elevation of our study area is below 1150 m, and the summer season receives the least amount of precipitation in this region. For this reason, the summer season is quite dry in the region. Fifteen plant taxa in the study area have adapted to dry conditions and marly soils during the vegetation period when the water deficit reaches its maximum.

Table 5- Spearman's correlations between plant taxa and environmental variables

Species		*N_1*	*N_2*	*Lime_2*	*P_1*	*P_2*	*OM_1*	*OM_2*	*Altitude*	*Slope*
Junoxy	r_s	0.409*	0.385*	0.026	0.435**	0.429**	0.451**	0,408*	-0.213	0.017
	p	0.013	0.020	0.883	0.008	0.009	0.006	0.013	0.213	0.921
Quepub	r_s	0.225	0.188	-0.170	0.379*	0.354*	0.272	0.222	-0.082	0.259
	p	0.186	0.273	0.321	0.023	0.034	0.109	0.193	0.633	0.127
Gloori	r_s	0.465**	0.416*	0.099	0.294	0.373*	0.406*	0.379*	0.038	-0.482**
	p	0.004	0.012	0.567	0.082	0.025	0.014	0.023	0.824	0.003
Jasfru	r_s	0.105	0.105	0.030	0.102	0.078	0.078	0.030	-0.143	0.372*
	p	0.543	0.542	0.863	0.555	0.650	0.653	0.863	0.404	0.026
Fesval	r_s	0.540**	0.425**	-0.034	0.486**	0.254	0.573**	0.355*	0.170	-0.322
	p	0.001	0.010	0.844	0.003	0.134	0.000	0.034	0.321	0.056
Genauc	r_s	-0.337*	-0.222	-0.334*	-0.496**	-0.361*	-0.466**	-0.371*	0.124	0.065
	p	0.044	0.193	0.047	0.002	0.031	0.004	0.026	0.472	0.707
Conphr	r_s	-0.350*	-0.196	0.133	-0.415*	-0.296	-0.361*	-0.250	-0.275	0.292
	p	0.037	0.253	0.440	0.012	0.080	0.030	0.141	0.105	0.084
Rhathy	r_s	0.260	0.301	0.353*	0.102	0.240	0.195	0.289	-0.471**	0.032
	p	0.126	0.074	0.035	0.554	0.159	0.254	0.088	0.004	0.852

r_s: Spearman correlation coefficient; p: Significance level; 1: 0-10 cm; 2: 10-30 cm; OM: Organic matter; N: Total nitrogen; P: Avaible phosphorus; significant at the level of *p<0.05; **p<0.01; Junoxy: *Juniperus oxycedrus* subsp. *oxycedrus*; Quepub: *Quercus pubescens*; Gloori: *Globularia orientalis*; Jasfru: *Jasminum fruticans*; Fesval: *Festuca valesiaca*; Genauc: *Genista aucheri*; Conphr: *Convolvulus phrygius*; Rhathy: *Rhamnus thymifolia*

Much of the soils across the semiarid and arid forested regions of Türkiye commonly have high lime content (Çalışkan & Boydak 2017). In the study, the lime content in the soils was quite high, generally over 30%. Compared to other species, *G. aucheri* was found in the areas where the lime in the soil was lower. However, these taxa grow in soils where lime reaches 90%. The same results were also reported by Balpınar et al. (2019). The lime rate in the soil varied from 6.32% and 90.77%, (Table 4).

The decrease in soil organic matter reduces soil fertility and increases erosion in some soils (McCauley et al. 2009). In vegetation recovery, the major variable is organic substances in the soil (Romero-Díaz et al. 2017). The amount of organic matter in the soil of the study area varied between 0.27% and 5.88% (Table 4). The study area is generally poor in terms of organic matter in the soil. The plant taxa in this research are tolerant of soils poor in organic matter. However, according to numerical analysis, some of the plant species in our study area, *J. oxycedrus, G. orientalis* and *F. valesiaca* prefer soils in which organic matter is slightly higher. These species are also tolerant of poor soils.

Soil reaction (pH) strongly affects the chemical solubility and availability of essential plant nutrients (Çepel 1995; McCauley et al. 2009), and the greatest intake of plant nutrients is in the pH range of 6.5–7.5 (Güneş et al. 2007). According to the statistical analysis, no relationship was found between the soil pH and the plant species. The soil pH of the study area varied between 7.75 and 9.05 (moderate to strongly alkaline) (Table 4). The soil reaction of all plant taxa was generally medium alkaline, with an average soil reaction of approximately 8.50. However, it was determined that all plant taxa grow in soil with a pH of 9 at a depth of 10-30 cm. The development of woody species has been observed to decrease slightly as the reaction in soil increased.

Pinus nigra subsp. *pallasiana* showed deformed development (short form) in the study area. Although the study area soils were not shallow, it is possible to clearly see the lateral root system of *P. nigra* subsp. *pallasiana*. Similarly, Atalay & Efe (2012) stated that the lateral root systems developed well in hard and less weathered serpentines and marly deposits. This observation may be explained by the fact that the level of pH and lime in marl soils was slightly lower in the upper layers of the soil.

It has been observed that the first colonised plants after land restoration and environmental degradation are herbaceous species (Cammeraat et al. 2005; Burylo et al. 2007). In marly soils, the most suitable plant forms in terms of soil reinforcement are shrubs and herbaceous species (Burylo et al. 2011). In a study conducted in soils developing on different bedrock, woody sub-shrub, root-sprouts and clonal species were identified as suitable forms for eroded lands (Guerrero-Campo et al. 2008). Our study indicated that the identified fifteen taxa are clonal, bunch and woody species could retain their vitality in the driest conditions as well. In woody species, these taxa can be considered as having a significant role in preventing erosion in marly areas via their aboveground and underground organs. The grasses and shrubs with high root density have the highest potential to reduce soil erosion rates (De Baets et al. 2007). Grasses and shrubs show greater resistance to loss of the topsoil than tree seedlings. After the first growing season, the roots of tree seedlings can fix the upper layers of soil to the bedrock, and they can act as restraint piles firmly anchoring the root-permeated soil to the bedrock (Styzcen & Morgan 2005; Burylo et al. 2011).

It is known that in the study region, with a decrease of soil depth in *Pinus nigra* subsp. *pallasiana* plantation areas, water and nutrient economy held in the soil are negatively affected (Güner et al. 2016). The eroded marly sites in this region have clay, alkaline and highly calcareous soils. Due to extreme conditions that limit plant growth in the marly areas, *Pinus nigra* subsp. *pallasiana*, *Quercus pubescens* and *Juniperus oxycedrus* subsp. *oxycedrus* do not grow normally, and therefore, grow to a shorter height than expected. Vegetation plays an essential role in the regulation of hydrological processes and soil properties. Plant cover decreases the destructive forces of rainfall that cause soil erosion (Vásquez-Méndez et al. 2010). In our study, in the eroded marly areas where soil depth is sufficient, other plant forms should be considered in addition to tree species for revegetation. Clonal plant species are more advantageous than tree seedlings in highly eroded areas (Guerrero-Campo et al. 2008) and seed germination is more limited in the badlands (Guàrdia et al. 2000).

4. Conclusions

The rate of regeneration is very low or insufficient in studies of marly soil revegetation. The first issue in revegetating marly soils is selecting which plant species must be used in developing vegetation. The second issue is determining which plant species are best for preventing erosion. In this study, the plant species that survived the drought phase and their ecological requirements were determined. The species utilised on degraded marly soils must be able to adapt to soils with high pH and lime in semiarid climatic conditions subject to drought. In the eroded marly areas, vegetation cover can be supported by planting seedlings of groundcover and woody species adapted to marly field conditions. The best plant species are those grown with the least loss in the redevelopment of vegetation and erosion in the marly areas. In areas with excessive erosion and, consequently, shallow soil, bunching and clonal plants, as well as chamaephytes, are preferable for the development of vegetation.

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