

Analysis of the soil conditions in the natural habitats of a climate-resistant species *Nerium oleander* L.

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ABSTRACT

As climate change intensifies, plant species with high adaptive capacity are gaining importance for sustainable landscaping and ecosystem resilience. *Nerium oleander* L., a widely used ornamental plant, is known for its ability to thrive under diverse environmental conditions and is naturally distributed in Türkiye. This study aims to characterize the soil properties of its natural habitats to assess its potential for climate-adaptive landscaping. Soil samples were collected from 22 locations across Türkiye where *N. oleander* grows naturally. The results revealed that the soils varied in texture from loamy to clayey-loamy and sandy, with pH levels ranging from slightly acidic to slightly alkaline. Salinity levels also differed, with soils classified as nonsaline, slightly saline, and very saline. Correlation analysis showed strong relationships between specific soil parameters, such as saturation and organic matter content, as well as exchangeable Mg and electrical conductivity. These findings confirm that *N. oleander* can tolerate a wide range of soil conditions, supporting its suitability for landscape applications, particularly in the face of climate change.

Keywords: Apocynaceae, landscape adaptation, pH, salinity, soil properties

INTRODUCTION

Climate change, whose effects have become increasingly pronounced in recent years, is causing environmental challenges, such as rising temperatures, droughts, and irregular precipitation. These adversities threaten the availability of natural resources, making it more difficult to meet the needs of living organisms. By 2030, global water demand is projected to increase by 50% (National Intelligence Council, 2012), which will directly impact humans, plants, and animals. As a result, a significant portion of existing water resources will be allocated to food production, leaving less for landscape irrigation.

To address this issue, sustainable landscaping practices must prioritize plant species with low water requirements and high drought resistance.

Today, many countries have already begun integrating genotypes that occur naturally in their flora and, at the same time, have low consumption of natural resources (Karaguzel, 2007; Benschop et al., 2010; Alam et al., 2013). It is considered very important that Türkiye has a very rich flora in this respect, with 10460 species, 2066 subspecies, 888 varieties, and 287 hybrid taxa (Ozhatay et al., 2022).

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One of the species in this rich flora is *Nerium oleander* L., the genus *Nerium*, a member of the Apocynaceae family, is monotypic, and has only one species. This widely distributed plant thrives in Mediterranean regions, parts of Africa, Asia, South America, and the Southern United States. It is also cultivated as an ornamental plant in parks and gardens. The species is considered native to the Mediterranean, Indian subcontinent, and Western China. The presence of *Nerium* around the Mediterranean Basin has been documented since the Miocene (Ergun, 1992; Mateu-Andrés et al., 2015).

Although it generally grows in humid and low places, it can reach an altitude of 2500 m in some areas, such as the Atlas Mountains (Senses, 2009). *Nerium* grows primarily along ephemeral streams, ravines, and other upland seasonal streams where flooding in spring and autumn is common; typically, these streams remain dry for several months during the summer (Mateu-Andrés et al., 2015). It grows naturally in Türkiye, especially in coastal areas where temperatures are high, such as the Mediterranean, Aegean, and Marmara regions (Ergun, 1992; Dik et al., 2013; Simsek, 2013).

According to the information in the Flora of Turkey (Davis, 1978), it is naturally distributed in Manisa, Çanakkale, Balıkesir, Muğla, Denizli, Aydın, Antalya, İçel, Adana, Hatay-İskenderun, and Adıyaman (as subsp. *kurdicum* Rech. fil., fide Rech. in litt.).

N. oleander is an evergreen, densely branched shrub or small tree that can grow up to 2–6 m tall. It is a fast-developing species with a hard and durable stem. While the bark of the body can be bright green, dark brown, and gray, its surface is mostly smooth. It is common to have more than one stem. When the twig of the plant is cut, sticky latex is released (Mamikoglu, 2007; Simsek, 2013; Celik, 2020).

The lanceolate leaves are 2–3 cm wide and 10–15 cm long, usually in groups of three. The leaf tips are acute, narrowing at the base, and terminating in a short stalk (Davis, 1978). The leaf blade is 6–30 cm × 1–3 cm in size. The midrib protrudes on the lower face; the side veins are almost perpendicular to the midrib and parallel, and both sides are naked and coriaceous. Its upper surface is dark, and its lower surface is light green (Ergun, 1992).

The flowers bloom between June and November and are located at the ends of the shoots. It is known that there are more than 400 *Nerium* cultivars, whose flower colors are mostly in shades of pink or white, with red, purple, yellow, and orange flower colors, rarely fragrant (usually those with layered flowers) (Davis, 1978; Simsek, 2013; Anonymous 1, 2022).

This species is highly adaptable to various soil types, including well-drained and heavy clay soils. It thrives in full sun or partial shade and exhibits remarkable tolerance to heat, drought, and salinity. It is well-suited for coastal areas, enduring salt-laden winds. While it can survive temperatures as low as -5°C and briefly

withstand -10°C , leaf damage may occur (Anonymous 1, 2022; Anonymous 2, 2022; Anonymous 3, 2022).

Extreme heat and drought caused by climate change, the effects of which we have felt more intensely in recent years, will adversely affect the existence of water resources and will also directly or indirectly affect the landscape and ornamental plants used in landscape design works and will lead to the emergence of partial changes. Given the increasing impact of climate change, extreme heat and drought conditions will continue to threaten water resources and landscape vegetation. This necessitates a shift toward drought-resistant species, such as *N. oleander*, which requires minimal water while thriving in challenging environments.

Therefore, this study aims to analyse soil characteristics in its natural habitats to assess potential limitations or preferences for its use in landscaping.

MATERIALS AND METHODS

This study's material consisted of soil samples collected from different locations where the *N. oleander* L. species naturally occurs in the flora of Türkiye.

The natural distribution locations of the species were identified based on from Flora of Turkey (Davis, 1978), ISTO (Istanbul University—Cerrahpasa Faculty of Forestry Herbarium), Istanbul University Faculty of Science Herbarium, and Istanbul University Faculty of Pharmacy Herbarium.

For this purpose, the provinces of Manisa, Çanakkale, Balıkesir, Muğla, Denizli, Aydın, Antalya, İçel, Adana, Hatay, and Adıyaman were selected as sampling locations. Although İzmir province is not recorded in Flora of Türkiye (1978), it was included in this study as part of the species' natural distribution. In total, 22 soil samples (Table 1) were collected from natural distribution areas across 12 provinces.

In July and August, 2023, soil samples were collected from a depth of 0–30 cm in the species' natural habitat, following standard procedures (Jackson, 1958). The samples were placed in polyethylene bags and labelled separately. The physical and chemical analyses of soil samples taken from different locations were conducted in three replicates at S.S. Nilufer Agricultural Development Cooperative Analysis Laboratory located in Ulutek Technopark.

For the classification of selected physical and chemical properties of soil samples, the following sources were used: Dewis and Freitas (1990) for exchangeable calcium (Ca) and magnesium (Mg); TSE (1990) for saturation content; Ulgen and Yurtsever (1995), Richards (1954), Grieve et al. (2011), and Ulgen and Yurtsever (1995) for electrical conductivity (EC) content; Eyupoglu (1999) for pH content; Hizalan and Unal (1966) for lime content; Anonymous (1985) for organic matter content; Olsen et al. (1954) for available phosphorus (P) content; and Pizer (1967) for exchangeable potassium (K) content.

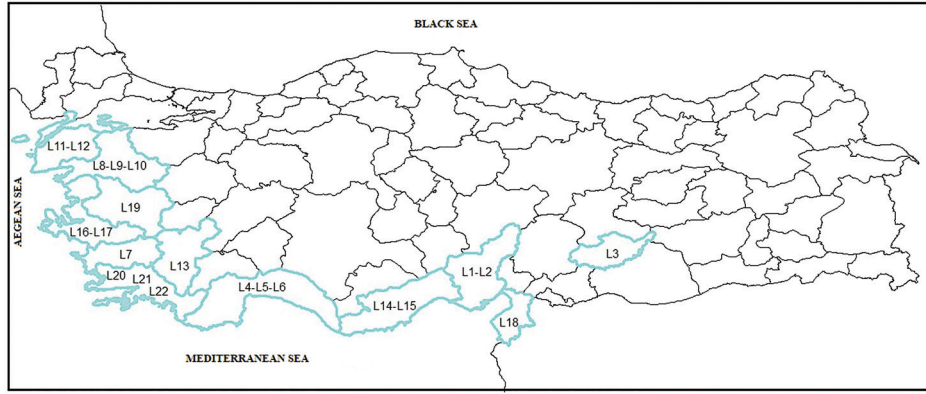


Table 1. Natural distribution areas where soil samples were taken.

Province	Location	Altitude (m)	Coordinate		
Adana	L1	141	37.4810172° N,	35.8301483°	E ± 7 m
	L2	268	37.4639207 N,	35.8075318°	E
Adıyaman	L3	724	37.880035° N,	38.5952181°	E ± 5 m
Antalya	L4	168	36.9287119° N,	31.7629229°	E ± 5 m
	L5	116	36.1753046° N,	32.4427024°	E ± 5 m
	L6	615	37.140.1636° N,	31.189035°1	E ± 7 m
Aydın	L7	97	37.5749658° N,	27.8260236°	E ± 5 m
Balıkesir	L8	38	39.270069° N,	26.8658451°	E ± 5 m
	L9	51	39.6140237° N,	26.9536938°	E ± 5 m
	L10	177	39.2579536° N,	26.8281544°	E
Çanakkale	L11	337	39.7007617° N,	26.3207911°	E ± 10 m
	L12	337	39.7007614° N,	26.3207911°	E
Denizli	L13	331	37.9522344° N,	29.1084182°	E ± 5 m
İçel	L14	20	36.8555178° N,	34.7484481°	E
	L15	717	36.2785009° N,	33.3887356°	E ± 5 m
İzmir	L16	45	38.6575786° N,	26.8096729°	E
	L17	87	38.4376547° N,	26.5468566°	E ± 5 m
Hatay	L18	73	36.3619489° N,	35.891514°	E ± 5 m
Manisa	L19	168	38.5863552° N,	27.3538664°	E
Muğla	L20	0	36.7527379° N,	28.118081°	E ± 5 m
	L21	0	37.4178917° N,	27.8200993°	E ± 5 m
	L22	652	36.7977692° N,	28.6484163°	E ± 16 m

Additionally, the elevation map of the sampling locations where the samples were classified into five categories, while the aspect map was divided into seven categories, both derived from the digital elevation model in ArcMap 10.2.2 (Esri Inc., Redlands, California, USA.) programme. On the contrary, maps of selected physical and chemical properties of soil samples from different locations were created using ArcMap 10.2.2 programme.

Climatic data of different locations

Meteorological data of the provinces where the distribution areas evaluated in this study were located

and where soil samples were taken from the website of the General Directorate of Meteorology (MGM) are given in Figures 1 and 2.

Statistical analysis

SPSS Version 28 (IBM SPSS, Armonk, NY, USA, 2022) software was used for statistical analysis of data obtained from the research. Before the analysis, normality plots with test histogram were made for the data, and it was seen that it had a normal distribution. A one-way analysis of variance (ANOVA) was used to assess selected physical and chemical properties of soil

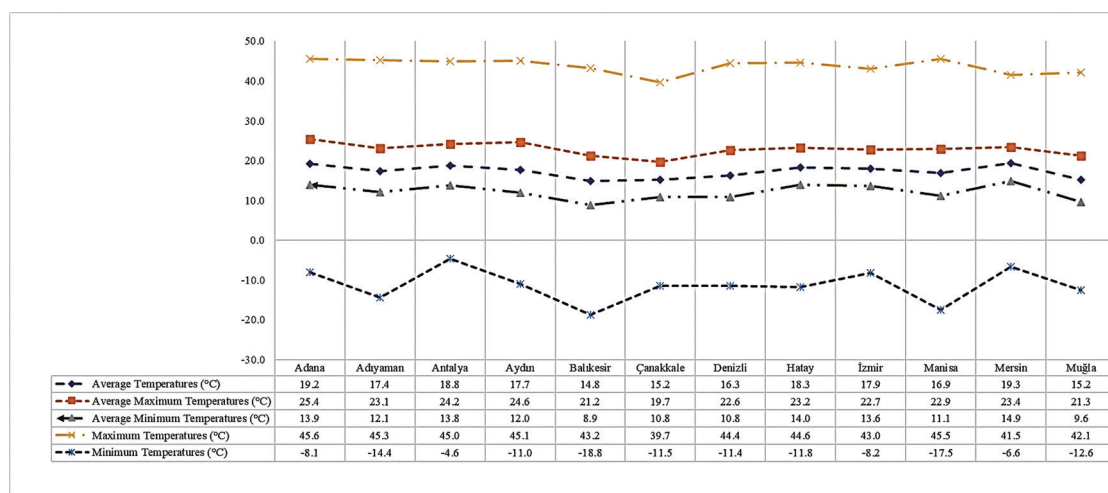


Figure 1. Long-term (1929–2024) average temperature values of the provinces where the natural distribution areas of *Nerium oleander* L. are located (MGM, 2024).

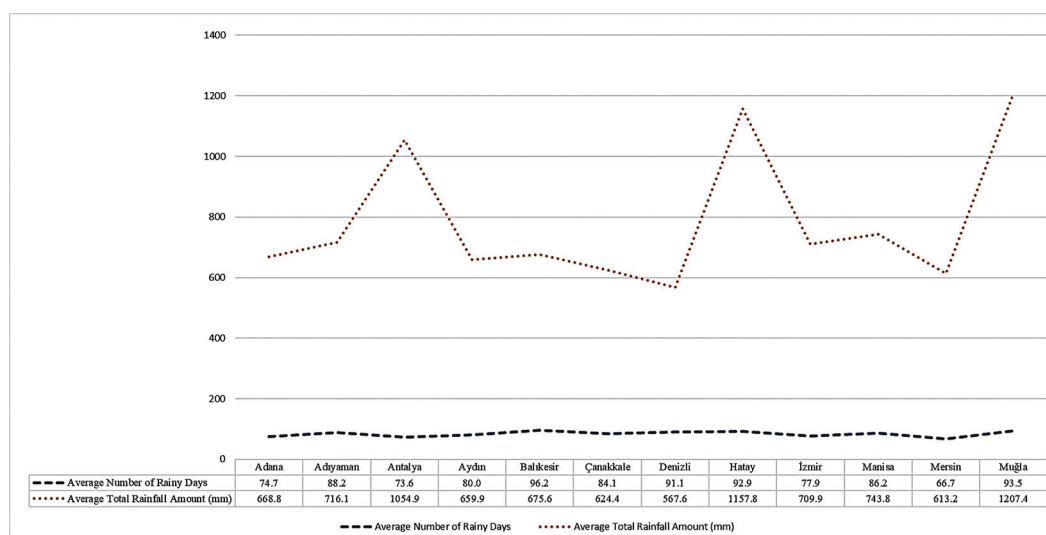


Figure 2. Long-term (1929–2024) average rainfall values of the provinces where the natural distribution areas of *Nerium oleander* L. are located (MGM, 2024).

samples. The statistical grouping of the obtained values was performed using the Duncan's multiple range test (Duncan, 1955) at a significance level of $p \leq 0.01$. In addition, Pearson correlation analysis was performed to examine the relationship between aspect, altitude, and soil properties of the species natural distribution areas.

RESULTS

Physical and chemical properties of soils from different locations

The lowest, highest, and average content of selected physical and chemical properties of the soil samples are given in Table 2. It was observed that in soil samples taken from different locations, the average exchangeable Ca content was $18.51 \text{ cmol Ca} \cdot \text{kg}^{-1}$, the average exchangeable Mg content was $4.21 \text{ cmol Mg} \cdot \text{kg}^{-1}$, the average saturation content was 45.32%, the average pH

Table 2. Minimum-highest and average content of selected physical and chemical properties of soil samples.

Soil properties	Minimum	Maximum	Average
Exchangeable Ca ($\text{cmol} \cdot \text{kg}^{-1}$)	5.99	37.25	18.51
Exchangeable Mg ($\text{cmol} \cdot \text{kg}^{-1}$)	0.23	30.51	4.21
Saturation (%)	25.74	70.62	45.32
pH	5.92	8.05	7.52
EC ($\text{dS} \cdot \text{m}^{-1}$)	0.08	28.00	1.75
Lime (%)	1.56	80.97	15.47
Organic matter (%)	0.06	6.67	1.50
Available P (ppm)	0.14	17.60	7.39
Exchangeable K ($\text{cmol} \cdot \text{kg}^{-1}$)	0.08	3.60	0.78

EC, electrical conductivity.

content was 7.52, the average EC content was $1.75 \text{ dS} \cdot \text{m}^{-1}$, the average lime content was 15.47%, the average organic matter content was 1.50%, the average available P content was 7.39 ppm, and the average exchangeable K content was $0.78 \text{ cmol K} \cdot \text{kg}^{-1}$.

On the contrary, according to the results of the analyses performed at the locations where the plants were distributed, selected physical and chemical properties of the soil, except pH, were found significant at the $p \leq 0.01$ level (Table 3).

It was observed that the content of exchangeable Ca varied between $5.99 \text{ cmol Ca} \cdot \text{kg}^{-1}$ and $37.25 \text{ cmol Ca} \cdot \text{kg}^{-1}$, and the highest content of Ca was in L20.

It was determined that 45.45% of the soil samples examined had high exchangeable Ca, and 54.55% had medium exchangeable Ca. It was observed that the content of exchangeable Mg varied between $0.23 \text{ cmol Mg} \cdot \text{kg}^{-1}$ and $30.51 \text{ cmol Mg} \cdot \text{kg}^{-1}$, and the highest Mg content was in L20. It was determined that 9.09% of the examined soils had very high, 9.09% high, 27.28% medium, 45.45% low, and 9.09% very low exchangeable Mg content (Table 3).

It was determined that the examined soils were in the sandy, loamy, and clayey-loamy texture classes, and it was observed that 72.72% of the soils were loamy, 4.55% were sandy, and 22.73% were clayey-loamy. The

Table 3. Selected physical and chemical properties and statistical groups of soil samples according to different locations.

Location	Saturation (%)	Texture class	pH	EC ($\text{dS} \cdot \text{m}^{-1}$)	Lime (CaCO_3) (%)	Organic matter (%)	Available P (ppm)	Exchangeable ions		
								Ca ($\text{cmol} \cdot \text{kg}^{-1}$)	Mg ($\text{cmol} \cdot \text{kg}^{-1}$)	K ($\text{cmol} \cdot \text{kg}^{-1}$)
L1	25.74 m	Sandy	7.55	0.61 def	14.05 g	0.26 fg	4.20 fg	16.84 f	0.32 jk	0.43 def
L2	41.47 ij	Loamy	7.85	0.27 fgh	41.49 c	1.90 cde	4.20 fg	20.43 e	0.55 ijk	0.54 def
L3	66.22 b	Clayey-loamy	7.86	0.56 defg	24.84 e	0.64 defg	0.15 i	29.49 b	7.18 d	0.35 def
L4	44.88 g	Loamy	7.82	0.35 efgh	1.71 m	0.06 g	9.40 d	8.48 i	0.67 ijk	0.89 cdef
L5	48.40 f	Loamy	7.68	0.55 defg	34.14 d	1.22 defg	0.14 i	19.45 e	1.19 hijk	0.09 f
L6	41.25 ij	Loamy	7.66	0.39 defgh	8.97 i	1.44 defg	1.30 hi	24.52 c	0.58 ijk	0.34 def
L7	42.68 hi	Loamy	7.13	0.43 defgh	3.76 kl	1.67 cde	20.60 a**	8.02 i	0.41 ijk	0.38 def
L8	37.95 k	Loamy	6.51	0.08 h	1.71 m	1.63 cdef	5.34 ef	5.99 j	0.61 ijk	0.24 ef
L9	36.85 k	Loamy	7.32	0.8 cd	1.73 m	0.81 defg	13.60 c	10.88 h	1.68 ghij	0.79 def
L10	40.81 j	Loamy	7.62	0.52 defg	2.21 lm	0.79 defg	14.00 c	12.90 g	1.75 ghi	0.86 cdef
L11	36.52 k	Loamy	7.67	0.22 fgh	2.53 klm	0.93 defg	13.40 c	11.37 h	0.96 hijk	0.39 def
L12	52.25 d	Clayey-loamy	7.93	1.07 c	4.10 k	0.55 efg	17.60 b	24.45 c	12.34 c	1.08 bcde
L13	43.67 gh	Loamy	7.90	0.52 defg	44.15 b	1.76 cde	2.41 h	22.74 d	2.91 efg	1.23 bcd
L14	51.15 d	Clayey-loamy	7.96	1.50 b	22.84 f	0.93 defg	4.37 fg	30.73 b	3.21 ef	1.70 bc
L15	50.60 de	Loamy	7.70	0.29 fgh	80.97 a**	3.68 b	8.47 d	19.67 e	0.50 ijk	0.25 ef
L16	49.06 ef	Loamy	5.92	0.4d efgh	1.56 m	1.20 defg	12.80 c	15.36 f	3.94 e	1.79 b
L17	47.96 f	Loamy	7.55	0.5d efgh	6.24 j	2.89 bc	1.07 hi	25.97 c	2.24 fgh	0.92 bcdef
L18	62.70 c	Clayey-loamy	7.46	0.76 cde	5.95 j	2.03 cd	5.00 f	16.95 f	19.98 b	0.75 def
L19	32.78 l	Loamy	8.05	0.16 gh	10.84 h	0.56 efg	2.40 h	15.88 f	0.48 ijk	0.37 def
L20	70.62 a**	Clayey-loamy	7.33	28.00 a**	10.07 hi	6.67 a**	6.65 e	37.25 a**	30.51 a**	3.60 a**
L21	36.63 k	Loamy	7.76	0.25 fgh	2.96k lm	0.53 efg	2.77 gh	17.11 f	0.55 ijk	0.18 ef
L22	36.85 k	Loamy	7.27	0.32 fgh	13.55 g	0.86 defg	12.76 c	12.84 g	0.23 k	0.08 f
Sig.	**		n.s.	**	**	**	**	**	**	**

**Letters indicate different groups at the $p \leq 0.01$ level.
EC, electrical conductivity; n.s., nonsignificant.

pH of the soils varied between 5.92 and 8.05. As a result of the evaluations, it was found that 59.09% of the soils were slightly alkaline, 31.81% were neutral, and 9.10% were slightly acidic. The EC content in soils varied between $0.08 \text{ dS} \cdot \text{m}^{-1}$ and $28.00 \text{ dS} \cdot \text{m}^{-1}$, and the highest EC content was discovered in L20 (Table 3).

The lime content of the soils varied between 1.56% and 80.97%, and it was observed that 18.18% of the soils had very high, 9.10% had high, 31.82% had medium, and 40.90% had low lime content. The organic matter content varied between 0.06% and 6.67%, and it was determined that 4.55% of the soils had very high, 4.55% had high, 4.55% had medium, 36.35% had low, and 50% had very low organic matter content (Table 3).

Maps of selected physical and chemical properties of soil samples from different locations are given in Figures 3–6.

Soil texture (sandy, clayey, loamy, etc.) affects organic matter that is retained in the soil and how quickly it decomposes. Depending on the disintegration

rate in different soil textures, the content of organic matter varied according to locations and varied between 0.06% and 6.67% (Table 3).

The available P content of the soil varied between 0.14 ppm and 20.6 ppm, and it was determined that 4.55% of the soils had high, 36.36% had medium, 27.27% had low, and 31.82% had very low available P content.

The exchangeable K content of the soil varied between $0.08 \text{ cmol K} \cdot \text{kg}^{-1}$ and $3.60 \text{ cmol K} \cdot \text{kg}^{-1}$, and it was determined that 36.36% of the soils contained very high, 9.10% high, 4.54% good, 13.64% medium, 18.18% low, and 18.18% very low exchangeable K (Table 3).

Physical and chemical properties of soils at different altitudes

According to the analyses performed at different altitudes, all physical and chemical properties except pH and organic matter were found significant at $p \leq 0.01$ (Table 4). The elevation map of the locations in the study area is given in Figure 7.

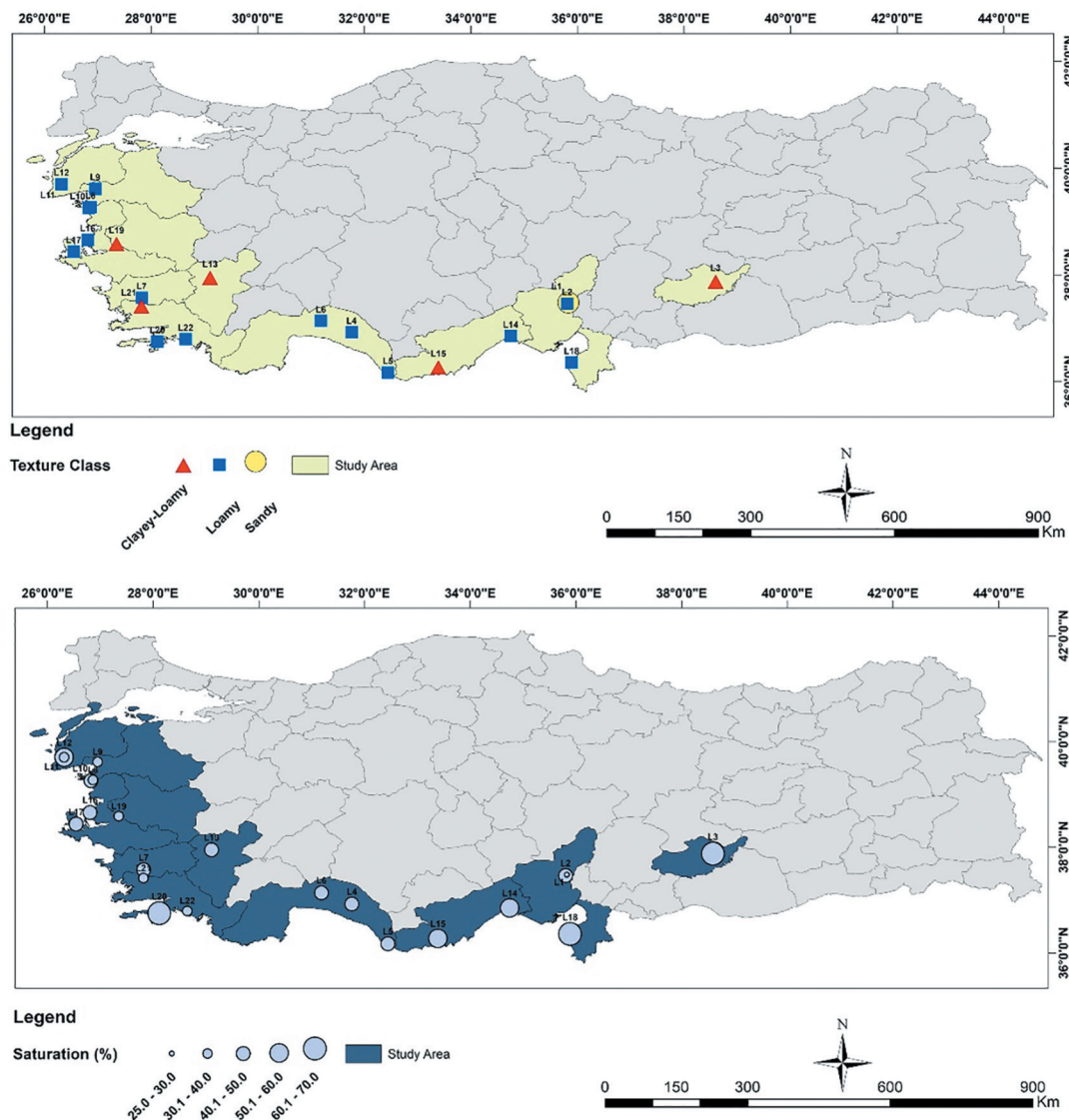


Figure 3. Texture class and saturation properties of soil samples according to different locations.

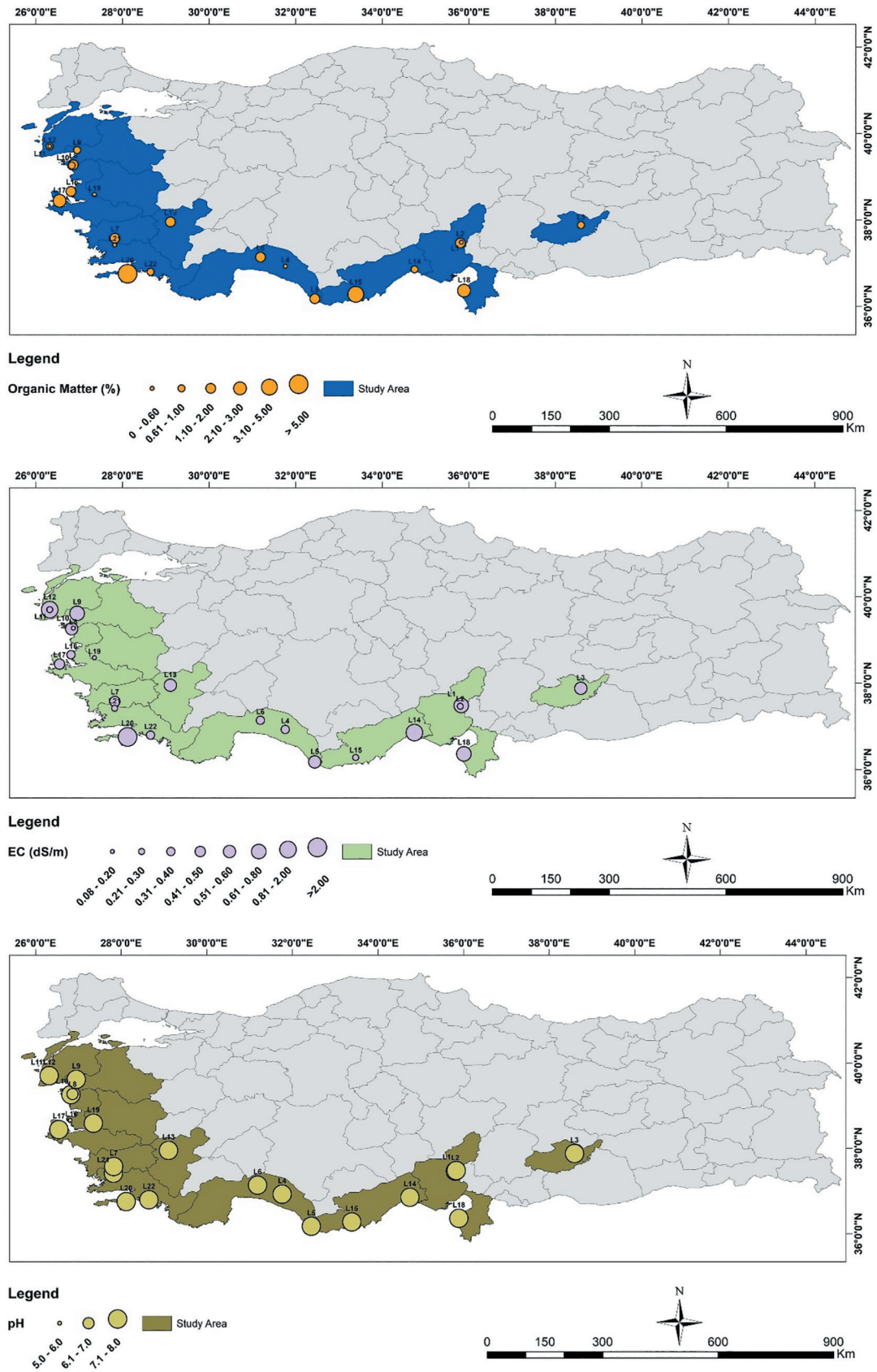


Figure 4. Organic matter, EC, and pH properties of soil samples according to different locations. EC, electrical conductivity.

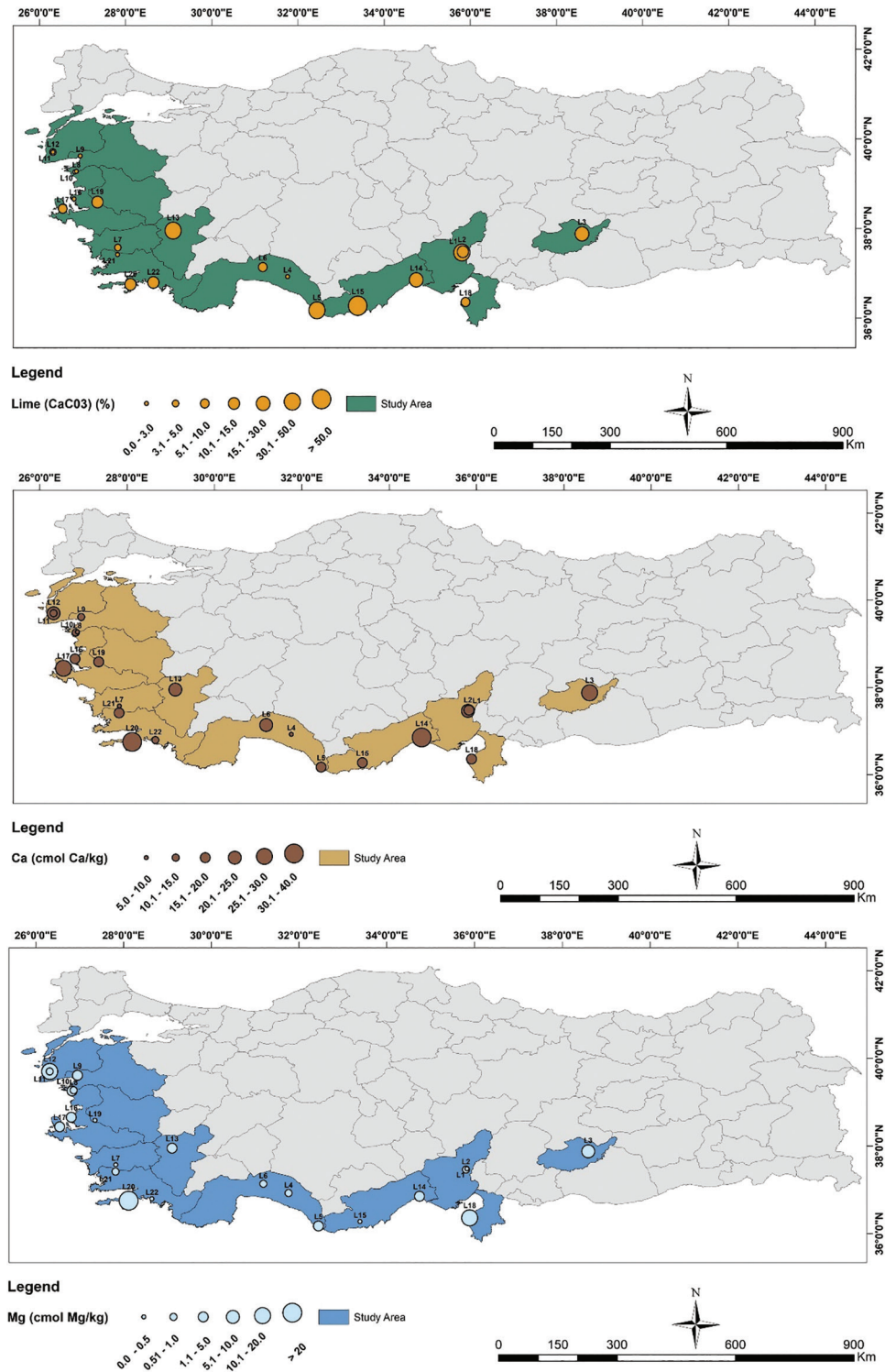


Figure 5. Lime, Ca, and Mg properties of soil samples according to different locations.

The evaluations observed that the soils taken from 0 m to 150 m, 301 m to 450 m, and 451 m to 750 m altitudes had a high exchangeable Ca content, while the soils from 151 m to 300 m had a medium exchangeable Ca content. It was determined that the content of exchangeable Mg was low in the samples taken from 151 m to 300 m altitudes, medium in the samples taken from 451 m to 750 m altitudes, and high in the samples

taken from 0 m to 150 m and 301 m to 450 m altitudes (Table 4).

The soils analysed at all altitudes were found to be in the loamy texture class. It has been observed that the pH content, which were found to be statistically insignificant according to the altitudes, varied between 7.28 and 7.83 (neutral—slightly alkaline). It was determined that the EC content ranged between $0.32 \text{ dS} \cdot \text{m}^{-1}$ and $3.08 \text{ dS} \cdot \text{m}^{-1}$

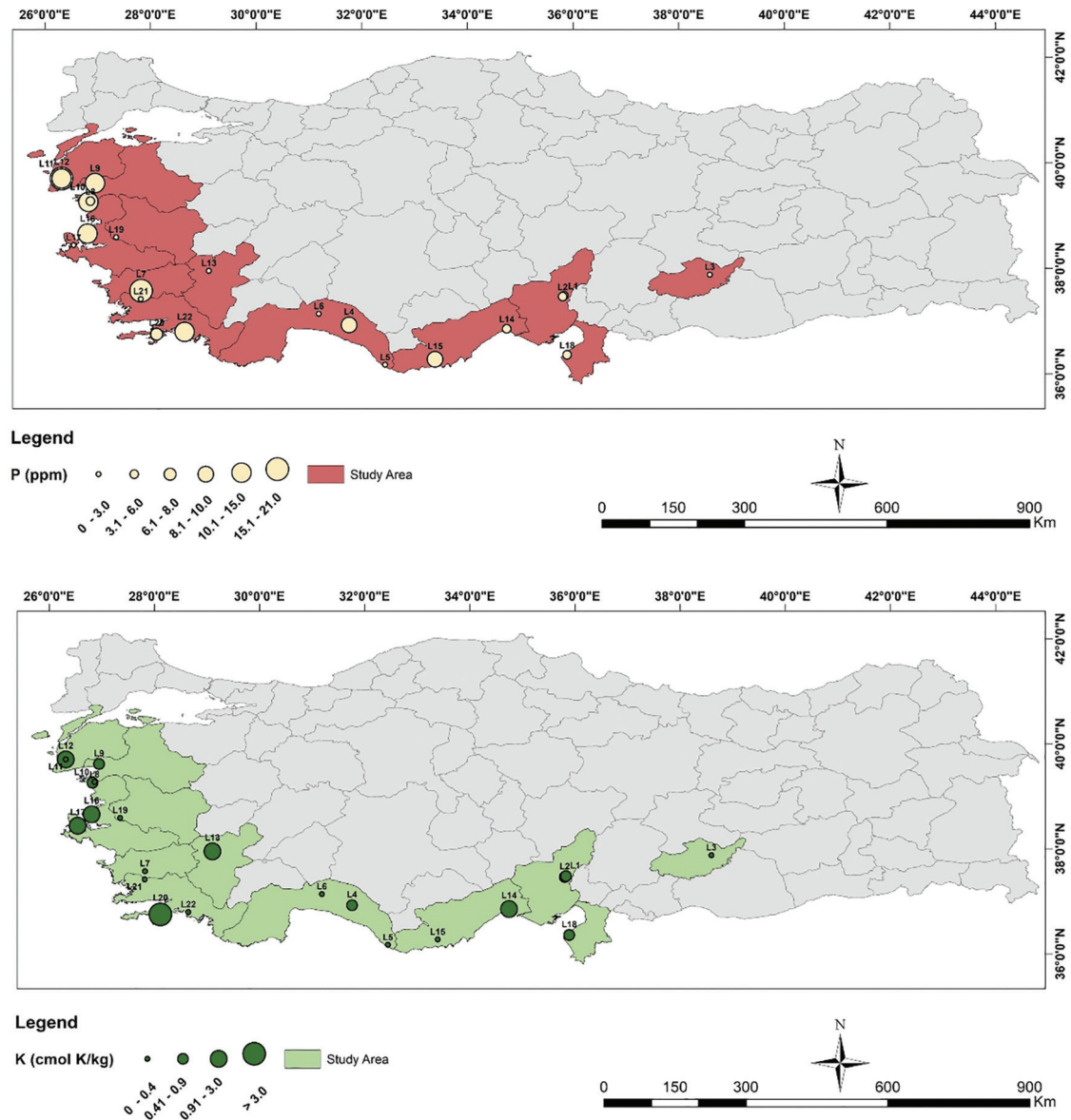


Figure 6. P and K properties of soil samples according to different locations.

at different altitudes; the soils taken from 151 m to 300 m, 301 m to 450 m, and 451 m to 750 m altitudes were nonsaline; and the soils taken from 0 m to 150 m altitude were slightly saline (Table 4).

It was observed that the content of lime was moderate in the soils taken from 0 m to 150 m and 151 m to 300 m altitudes, high in the soils taken from 301 m to 450 m altitudes, and very high in the soils taken from 451 m to 750 m altitudes. The soils were in the very low-low range, and the highest content of organic matter was found in the samples taken from between 0 m and 150 m altitudes, which was 1.8% (Table 4).

The available P content of the soils was found to be at a medium level in the samples taken from 151 m to 300 m and 301 m to 450 m altitudes and at a low level in the samples taken from 0 m to 150 m and 451 m to 750 m altitudes. On the contrary, the content of exchangeable K was found to be very high at altitudes of 0–150 m and

301–450 m, high at altitudes of 151–300 m, and low at altitudes of 451–750 m (Table 4).

Physical and chemical properties of soils according to different aspects

According to the results of the analyses performed according to different aspects, all physical and chemical properties except pH, organic matter, and potassium were found significant at the $p \leq 0.01$ level (Table 5). The aspect map of the locations in the study area is given in Figure 8.

As a result of the evaluations, it was determined that the soil samples with a southwest aspect had the highest content in terms of exchangeable Ca, Mg, and EC. On the contrary, the lowest content of exchangeable Ca, Mg, EC, lime, available P, and exchangeable K was detected in the soils located in the North, Northeast, West, North, Southeast, and West aspects, respectively.

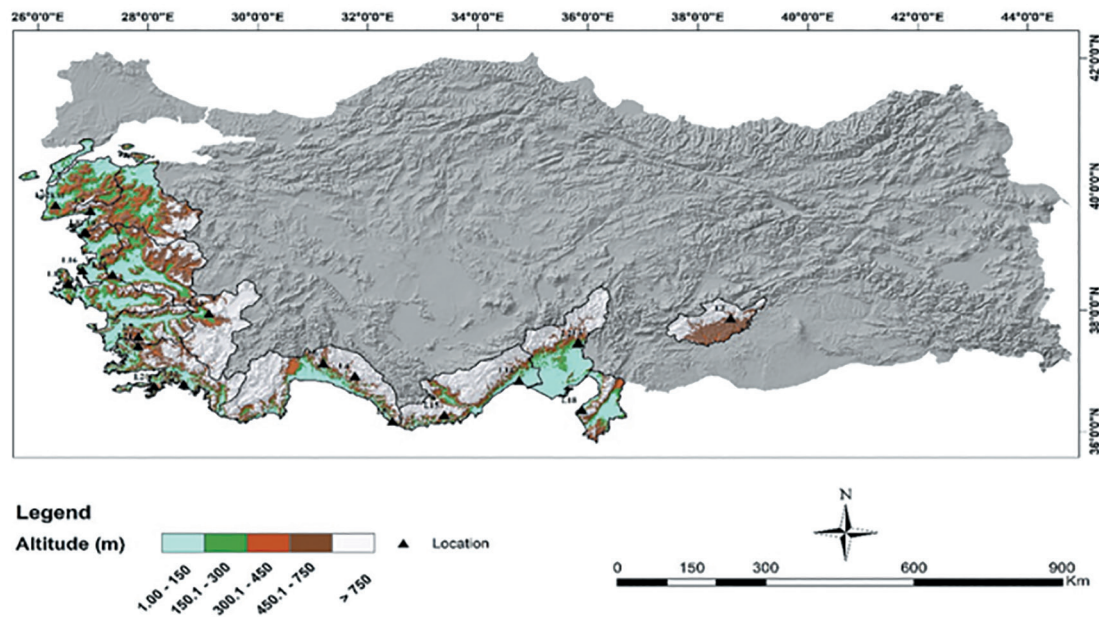


Figure 7. Elevation map of the locations.

Table 4. Selected physical and chemical properties of soil samples at different altitudes.

Altitude (m)	Saturation (%)	Texture class	pH	EC (dS/m)	Lime (CaCO ₃) (%)	Organic matter (%)	Available P (ppm)	Exchangeable ions		
								Ca (cmol · kg ⁻¹)	Mg (cmol · kg ⁻¹)	K (cmol · kg ⁻¹)
0–150	46.34 b	Loamy	7.28	3.08 a**	9.54 d	1.80	6.96 b	18.60 b	5.87 a**	0.99 a**
151–300	39.98 d	Loamy	7.83	0.32 b	14.06 c	0.82	7.50 b	14.42 c	0.86 b	0.67 b
301–450	44.14 c	Loamy	7.83	0.60 b	16.92 b	1.08	11.13 a**	19.52 b	5.40 a**	0.90 a**
451–750	48.73 a**	Loamy	7.62	0.39 b	32.08 a**	1.65	5.67 b	21.63 a**	2.12 b	0.26 c
Sig.	**		n.s.	**	**	n.s.	**	**	**	**

**Letters indicate different groups at the $p \leq 0.01$ level.

EC, electrical conductivity; n.s., nonsignificant.

It was determined that the examined soils were in the loamy texture class in the North, South, East, West, and Southeastern aspects, sandy in the Northeast aspect, and clayey-loamy in the Southwest aspect. It was found that the soils taken from the Southeast and Southwest aspects had a slightly alkaline reaction, while the soils taken from all other aspects had a neutral reaction. Although the content of organic matter in the soils was statistically insignificant, it was determined that the highest content of organic matter was found in the soils with the southwest aspect, followed by the soils with the north-facing aspect.

The correlation between altitude and soil properties

As a result of the Pearson correlation analysis performed to determine whether there is a relationship between the physical and chemical properties of the soils located at

different altitudes, it was seen that the soil properties were not related to each other (Table 6).

On the contrary, due to the Pearson correlation analysis between the physical and chemical properties of soils in different aspects, a high level of correlation was found between selected soil properties. There was a positive relationship between magnesium and EC and exchangeable K at the $p \leq 0.01$ level and between organic matter at $p \leq 0.05$. It was determined that there was a positive relationship between saturation and organic matter and between EC and exchangeable K at the $p \leq 0.01$ level (Table 7).

DISCUSSION

This study was carried out to reveal the similarities or differences between the soil conditions of *N. oleander*

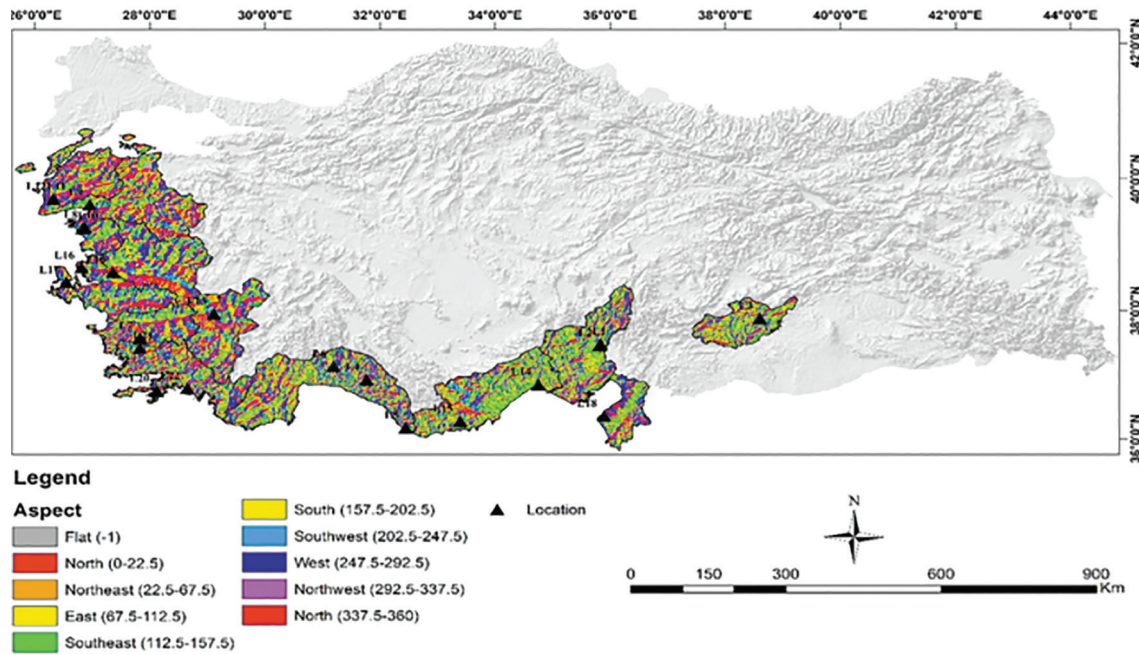


Figure 8. Aspect map of the locations.

Table 5. Selected physical and chemical properties of soil samples according to different aspects.

Aspect	Saturation (%)	Texture class	pH	EC (dS · m ⁻¹)	Lime (CaCO ₃) (%)	Organic matter (%)	Available P (ppm)	Exchangeable ions		
								Ca (cmol Ca · kg ⁻¹)	Mg (cmol · kg ⁻¹)	K (cmol · kg ⁻¹)
North	42.68 d	Loamy	7.13	0.43 d	3.76 e	1.67	20.6 a**	8.02 e	0.41d	0.38 b
South	48.22 b	Loamy	7.35	0.42 d	8.91 d	1.34	3.62 e	22.49 ab	2.90 bc	0.72 b
East	45.72 c	Loamy	7.65	0.62 b	22.53 b	1.58	9.00 c	17.56 c	4.09 b	0.75 b
West	35.86 e	Loamy	7.27	0.18 e	8.70 d	1.01	6.83 d	11.57 d	0.44 d	0.23 b
Northeast	25.74 f	Sandy	7.55	0.61 b	14.05 c	0.26	4.20 e	16.84 c	0.32 d	0.43 b
Southeast	46.03 c	Loamy	7.79	0.53 c	39.14 a**	1.49	1.27 f	21.09 b	2.05 c	0.66 b
Southwest	55.91 a**	Clayey-loamy	7.69	9.80 a**	5.29 e	2.42	11.21 b	23.39 a**	14.51 a**	1.86 a**
Sig.	**		n.s.	**	**	n.s.	**	**	**	n.s.

**Letters indicate different groups at the $p \leq 0.01$ level.

EC, electrical conductivity; n.s., nonsignificant.

species, which has a natural distribution in different localities in the flora of Türkiye, and it was determined that the species has a natural distribution within the borders of 12 provinces in Türkiye. Within the scope of the study, soil samples taken from 22 different localities where the species has a natural distribution were analysed in terms of physical and chemical properties.

It has been observed that *N. oleander* L., one of the maquis formation plants, which is the characteristic plant formation of the Mediterranean climate, distributes naturally in coastal areas, dry waterways, and valleys and that the altitudes of the places where soil samples

were taken vary between 0 m and 724 m and that they do not distribute naturally above this altitude limit. It has been observed that the species has a natural distribution in localities with the Mediterranean climate type, and its distribution areas are restricted due to the decrease in temperatures and climate type changes at altitudes of ≥ 750 m. As a matter of fact, researchers, such as Davis (1978) and Aksoy and Ozturk (1997), reported that the distribution height of the species is at most 800 m. In all natural distribution areas examined for the species, it was determined that the average temperature is 17.3°C, the average highest temperature is 22.9°C, the average

Table 6. Pearson correlation analysis of soil properties at different altitudes.

Altitude	Exchangeable Ca	Exchange Mg	Saturation	pH	EC	Lime	Organic matter	Available P	Exchangeable K
Exchangeable Ca	1								
Exchangeable Mg	0.386	1							
Saturation	0.931	0.354	1						
pH	-0.288	-0.505	-0.578	1					
EC	0.054	0.694	0.294	-0.911	1				
Lime	0.656	-0.433	0.569	0.238	-0.595	1			
Organic matter	0.682	0.451	0.890	-0.886	0.664	0.206	1		
Available P	-0.100	0.468	-0.399	0.505	-0.170	-0.369	-0.539	1	
Exchangeable K	-0.346	0.730	-0.349	-0.249	0.624	-0.916	-0.087	0.598	1

Correlation is found to be insignificant.

EC, electrical conductivity.

Table 7. Pearson correlation analysis of soil properties at different aspects.

Aspect	Exchangeable Ca	Exchange Mg	Saturation	pH	EC	Lime	Organic matter	Available P	Exchangeable K
Exchangeable Ca	1								
Exchangeable Mg	0.611	1							
Saturation	0.510	0.731	1						
pH	0.744	0.479	0.272	1					
EC	0.485	0.963**	0.594	0.387	1				
Lime	0.334	-0.203	0.002	0.696	-0.310	1			
Organic matter	0.288	0.762*	0.942**	0.195	0.682	-0.112	1		
Available P	-0.616	0.128	0.189	-0.541	0.206	-0.599	0.442	1	
Exchangeable K	0.691	0.987**	0.744	0.542	0.942**	-0.126	0.747	0.071	1

**0.01, *0.05.

EC, electrical conductivity.

lowest temperature is 12.12°C, the lowest temperature is -11.37°C, the highest temperature is 43.75°C, and the average annual precipitation amount is 783.28 mm.

According to the limit values reported by TSE (1990), Ulgen and Yurtsever (1995), it was observed that 22.73% of the soils in the areas where the plant was naturally distributed were clayey-loamy, 72.72% loamy, and 4.55% sandy textures. Moreover, according to Eyupoglu (1999), it was observed that 59.09% of the soils were slightly alkaline, 31.81% were neutral, and 9.10% were slightly acidic.

N. oleander is a species that can adapt to many soil conditions, such as poor, sandy, etc. (Uslu et al., 2018) and can withstand different soil reactions (acid-alkaline-neutral). The species easily adapt to pH levels between

5.0 and 8.3 (Gilman et al., 1993). In fact, the species has been detected in Rio Tinto, (Huelva Province, Andalusia, Spain), one of the world's largest hyper acidic environments, in vegetation tolerant to water, sediments, and soils with pH <3 and high S, Fe, Cu, and other metal concentrations (Rufo et al., 2011). It was observed that soil pH levels varied between 5.92 and 8.05 in the natural distribution areas examined.

The average exchangeable Ca content of soil samples taken from different locations was 18.51 cmol Ca · kg⁻¹ (Table 2), and according to the limit values reported by Dewis and Freitas (1990), it has been determined that 54.55% of the soils had medium levels of exchangeable Ca and 45.45% had high levels of exchangeable Ca.

The average exchangeable Mg content was found to be $4.21 \text{ cmol Mg} \cdot \text{kg}^{-1}$ (Table 2). According to the limit values reported by Dewis and Freitas (1990), it was determined that 9.09% of the soils had very low, 45.45% low, 27.28% had medium, 9.09% high, and 9.09% very high levels of exchangeable Mg.

On the contrary, according to the limit values reported by Richards (1954); Grieve et al. (2011); and Ulgen and Yurtsever (1995), it has been determined that 86.36% of the soils in which the plants distributed were found to be nonsaline, 9.10% were found to be very slightly saline and 4.54% were found to be very saline.

The results showed that the species are resistant to soils with a wide range of salinity, including very saline, slightly saline, and nonsaline, as well as saline conditions and salty winds by the sea. Researchers, such as Gilman et al. (1993); Lenzi et al. (2009), and Seridou et al. (2023), reported that the species is resistant to salt in their studies.

On the contrary, the lime content in the soils of natural distributing areas (Hizalan and Unal, 1966) was found to be high at only 9.10% and very high at 18.18%. It was determined that there was an increase in the content of lime in the soils in which the plants distribute due to the increase in altitude.

According to the limit values reported by Anonymous (1985), it was observed that the amount of organic matter in 86.35% of the examined soils was very low and at low levels. This suggests that the species can easily adapt to soil conditions where the content of organic matter is low or very low. As a matter of fact, researchers, such as Trigueros et al. (2012), and Uslu et al. (2018), stated in their studies that the species could easily develop in poor marginal lands and nutrient-deficient soils.

It was determined that only 4.55% of the examined soils were high in terms of available P (Olsen et al., 1954) and 36.36% were very high in terms of exchangeable K (Pizer, 1967).

On the contrary, it was found that there was a 1% statistically positive correlation between the EC content of the soils located in different aspects (Figure 8) and the potassium and magnesium content of the soils. The main reason for this relationship can be explained as the increase in the EC content of the soils due to the presence and increase in the concentration of Mg salts in the soil.

A positive correlation was obtained between the organic matter content and saturation levels of soils at a 1% statistical level. The main reason for this correlation can be shown as the increase in the saturation capacity of soils in parallel with the increase in their organic matter content.

CONCLUSIONS

N. Oleander, which is one of the native plants of the Mediterranean region and is of great ornamental interest, can adapt to adverse environmental conditions

(Bañon et al., 2006), can also withstand long-term droughts because it has some xerophytic adaptations (Lenzi et al., 2009; Sinha and Biswas, 2016), and has been found naturally in areas with quite different soil conditions. The results showed that *N. oleander* can easily adapt to areas with different soil conditions. This suggests that the species may be preferred to be used in landscaping areas with different soil properties and also as a potted plant in the coming years, which will experience rapid change due to climate change.

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AUTHOR CONTRIBUTIONS

M.Z., S.S.M., and B.H.C. developed the concept, conducted the research, and curated the data. M.Z. developed the methodology, conducted the formal analysis, wrote the original draft, and helped in reviewing and editing. B.H.C. performed formal analysis, reviewed, and edited the manuscript. All authors read and approved the final draft.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this article.

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