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Soil-Ecological Characteristics and Biodiversity of the Caspian Coastal Areas of Azerbaijan

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Abstract

The Caspian coastal zone of Azerbaijan is characterized by considerable diversity of soil and vegetation conditions, which are strongly influenced by salinity, moisture regime, sediment composition, hydrological conditions, and anthropogenic pressure. The aim of this study was to characterize the main soil types and associated plant communities and to assess their ecological relationships in the coastal and near-coastal territories of Azerbaijan. The study covered the Absheron Peninsula, Lankaran region, Kura-Araz Lowland, and Samur-Devechi Lowland. Field observations and soil analyses were used to characterize the main soil properties, including moisture, pH, humus content, salinity, and particle-size composition. Plant species associated with different soil types were recorded and classified according to their ecological characteristics. The results showed that soil conditions strongly influence the composition and distribution of coastal vegetation. Saline soils were mainly associated with halophytic and xero-halophytic species, whereas hydromorphic and alluvial soils supported predominantly hydrophytic, hygrophilous, and mesophytic vegetation. Sandy coastal soils were characterized mainly by xerophytic and psammophytic species, while takyr-like soils supported predominantly drought- and salt-tolerant plants. The study highlights the close relationship between soil properties, vegetation composition, and biodiversity in the Caspian coastal landscapes of Azerbaijan. The results provide a basis for further monitoring, conservation, and sustainable management of vulnerable coastal ecosystems.

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1. INTRODUCTION

The Caspian coastal zone of Azerbaijan represents an environmentally diverse and vulnerable region characterized by considerable variation in soil, hydrological, and vegetation conditions. The coastal landscapes include semi-desert, wetland, sandy, meadow, and aquatic ecosystems, with soil formation determined by the interaction of climate, relief, parent materials, groundwater, vegetation, and other soil-forming factors (Mamadov, 1998). The coastal zone also possesses important natural and recreational resources that contribute to the socioeconomic significance of these territories (Khudiyeva, 2019). The Caspian coastal territories contain a diverse range of soils, including gray-brown, alluvial-meadow, meadow-gray, saline, Solonetzic, sandy, hydromorphic, and marsh soils. Differences in soil moisture, salinity, texture, groundwater conditions, and sedimentary processes create distinct habitats for plant communities.

Consequently, the coastal vegetation includes xerophytic, halophytic, xero-halophytic, hydrophytic, hygrophilous, and mesophytic species adapted to contrasting environmental conditions.

Recent phytosociological studies have demonstrated a high diversity of aquatic and halophytic plant communities in Azerbaijan, including coastal swamp, wet grassland, aquatic forest, and hydrohalophytic associations, highlighting the ecological importance of Caspian coastal habitats (Atamov & Musayev, 2026). The ecological condition of the Caspian coastal zone is increasingly influenced by natural and anthropogenic pressures. Oil extraction and industrial activities have caused substantial soil degradation and contamination, particularly on the Absheron Peninsula (Aslanov, 2005; Aslanov & Safarli, 2008; Ismayilov, 2005). More recent studies emphasize the cumulative effects of pollution, hydrological changes, and other anthropogenic pressures on the Caspian environment and its biological resources (Bodini et al., 2024; Lahijani et al., 2024). Changes in the hydrological regime of the Volga River, the principal freshwater contributor to the Caspian Sea, also influence fluctuations in Caspian Sea level (Safarov et al., 2024).

Recent environmental assessments have emphasized the need for improved pollution monitoring, biodiversity planning, and integrated management of the Caspian coastal environment (UNOPS, 2026). Changes in soil moisture and salinity associated with hydrological fluctuations may directly affect the distribution and composition of coastal plant communities. Therefore, understanding soil-vegetation relationships is important for evaluating the ecological stability and conservation status of coastal ecosystems. Although individual soil types and plant communities of the Caspian coastal territories have been investigated, an integrated assessment linking the major soil groups with their associated vegetation across the principal coastal regions of Azerbaijan remains important. In particular, the relationships between soil conditions and the distribution of halophytic, xerophytic, xero-halophytic, hydrophytic, and other ecological plant groups require further consideration. Therefore, the aim of this study was to characterize the main soil types and associated plant communities of the Caspian coastal and near-coastal territories of Azerbaijan and to identify the principal relationships between soil conditions, vegetation composition, and plant biodiversity.

2. RESEARCH METHODS

Time and Place

The study was conducted in the coastal and near-coastal territories of Azerbaijan along the Caspian Sea. The study area encompassed the principal coastal regions and adjacent lowlands, including the Absheron Peninsula, Lankaran region, Kura-Araz Lowland, and Samur-Devechi Lowland. These territories represent contrasting geomorphological, hydrological, and soil-forming conditions and contain diverse soil-vegetation complexes.

Method

The research focused on the identification and ecological characterization of the principal soil types occurring in the Caspian coastal zone and their associated vegetation communities. Particular attention was given to saline and salt-affected soils, hydromorphic soils, alluvial-meadow soils, sandy coastal soils, and takyr-like soils. The assessment was based on field observations, available soil information, and analysis of the relationship between soil properties and vegetation composition.

Soil assessment and classification

Soil assessment considered the principal diagnostic and ecological properties relevant to the distribution of coastal vegetation, including soil moisture conditions, pH, humus content, salinity, particle-size composition, carbonate accumulation, and signs of hydromorphism and gleying. These characteristics were used to distinguish the major soil environments and to interpret their ecological relationships with plant communities.

The identified soils were correlated with the World Reference Base for Soil Resources (WRB) classification system. The WRB equivalents were assigned according to the diagnostic

characteristics reported for the respective soil groups. Particular attention was given to salinity, hydromorphism, carbonate accumulation, soil moisture regime, and parent material, as these properties are important for differentiating the principal coastal soil environments (Gersimova, 2018; IUSS, 2022). Detailed descriptions of the physicochemical properties and distribution of individual soil types are presented in the Results and Discussion section rather than repeated in the methodological description.

Vegetation assessment

Vegetation assessment was based on field observations of plant communities associated with the identified soil types and coastal landscape units. Plant species occurring under different soil and moisture conditions were recorded and grouped according to their principal ecological adaptations, including xerophytes, halophytes, xero-halophytes, hydrophytes, hygrophilous, and mesophytic species. The species composition was compared among the principal soil environments to identify characteristic plant groups and species associated with saline, sandy, alluvial, and hydromorphic conditions. The assessment also considered the occurrence of herbaceous, woody, aquatic, and halophytic vegetation within the studied coastal landscapes. Scientific names of plant species were standardized according to accepted botanical nomenclature. The resulting soil-vegetation relationships were used to characterize the ecological differentiation of coastal landscapes and to assess the role of soil conditions in determining plant-community composition.

3. RESULTS AND DISCUSSION

Soil diversity and environmental conditions of the Caspian coastal areas

The Caspian coastal and near-coastal territories of Azerbaijan are characterized by considerable diversity of soil and environmental conditions. The studied landscapes include saline, sandy, alluvial, meadow, hydromorphic, marsh, and takyr-like soils, whose development is controlled by differences in relief, parent materials, groundwater conditions, soil moisture, salinity, and sedimentary processes (Mammadov, 1998). The environmental conditions of the Caspian coastal zone are also strongly influenced by changes in the hydrological regime and sea level. Long-term observations have demonstrated substantial fluctuations in the Caspian Sea level, while recent studies indicate that future changes may be associated with climate variability, river discharge, evaporation, and water extraction (Chen et al., 2017; Korivhe et al., 2021; Lahijani et al., 2023; Samant & Prange, 2023). Changes in the Volga River discharge, which represents the major freshwater contribution to the Caspian Sea, may also affect the hydrological balance of the sea (Georgiadi & Milyukova, 2022; Svetesheva et al., 2022).

Projected changes in temperature and precipitation may further influence the hydrological conditions of the Caspian coastal zone. Climate projections indicate possible changes in precipitation intensity along the southern Caspian coast and alterations in temperature and precipitation regimes over the Caspian region (Zarrin & Dadashi-Roudbari, 2022; Hoseini et al., 2024). These changes may indirectly affect soil moisture, groundwater conditions, salinity, and the distribution of plant communities. Between 1880 and 1977, the Caspian Sea level declined by approximately four metres, from about -25 m to -29 m relative to mean sea level, apart from shorter periods during which the level rose slightly. Such long-term fluctuations may influence coastal geomorphology, groundwater conditions, soil moisture, salinity, and vegetation distribution (Figure1).

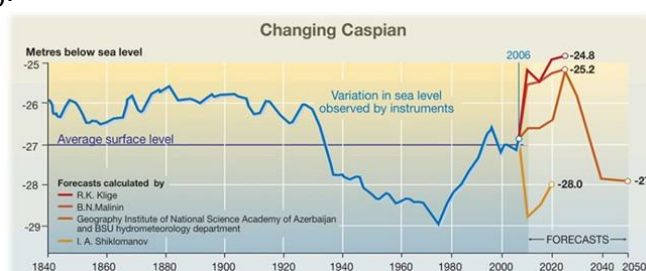


Figure 1. Fluctuations in the Caspian Sea level

The identified soil diversity was accompanied by pronounced differences in vegetation composition. Salinity, soil moisture, texture, and groundwater conditions act as important ecological filters determining the distribution of plant species. Thus, saline soils support predominantly halophytic and xero-halophytic vegetation, whereas moist and hydromorphic soils favour hydrophytic and hygrophilous communities. The environmental condition of the Caspian Sea and its coastal territories is also affected by pollution and other anthropogenic pressures. The Caspian Sea: State of the Environment 2019 assessment emphasized the importance of coordinated monitoring and protection of the marine and coastal environment (Tehran Convention, 2020).

Soils Distributed in the Caspian Coastal Areas

Caspian flora and fauna, including wetlands and shoreline ecosystems, are impacted by changes in water level and other human-induced factors, including alterations in nutrient balance and organic matter associated with agricultural expansion and dam development, overfishing, and anthropogenic climate change. Warming trends and human activities have also contributed to changes in the Caspian environment and biological resources (Lahijani et al., 2024). Species decline arising from multiple cumulative stressors has been documented in the Caspian ecosystem (Bodini et al., 2024).

Depending on environmental conditions, different plant communities develop on the various soil types described below. Representative images of different soil profiles observed in oil-contaminated areas are presented in Figures 2 and 3. Grey-brown soils (Calcisols). Grey-brown soils occur under relatively warm and dry climatic conditions. The sum of active temperatures above 10°C ranges from approximately 2450 to 4600°C, while the number of days with air temperatures above 10°C varies between 250 and 285 days.



Figure 2. Oil-contaminated soil profile



Figure 3. Oil-contaminated soil area

Their particle-size distribution is predominantly sandy loam to loam, and their structure is generally fine-granular. Soil colour ranges from light brown to greyish tones. The illuvial horizons commonly show carbonate and gypsum accumulation and, locally, signs of salinity, compaction, and stoniness. The parent materials are predominantly carbonate-rich loamy and sandy-loam loess-like deposits and marine sediments. Under irrigation, grey-brown soils tend to have a heavier texture, ranging from heavy loam to light clay, with relatively high proportions of silt and clay particles. Humus content is comparatively low (1.5-1.9%).

The natural vegetation associated with these soils is predominantly xerophytic, xero-halophytic, and ephemeral, reflecting the relatively dry environmental conditions. Characteristic species include *Artemisia lerchiana*, *A. fragrans*, *Salsola nodulosa*, *Alhagi pseudalhagi*, *Calligonum aphyllum*, *Suaeda altissima*, and *Atriplex cana*. Ephemeral species include *Hordeum leporinum*, *Bromus tectorum*, and *Avena fatua*. The dominance of drought-tolerant species indicates strong adaptation to limited soil moisture and, in some locations, increased salinity. This relationship between environmental conditions and plant-community distribution is consistent with previous phytogeographical studies of the Caspian coastal zone (Dimeyeva, 2013).

Grey soils (Calcisols) are widespread in the semi-desert and dry-steppe zones of Azerbaijan, particularly on the Absheron Peninsula, Kura-Araz Lowland, and Caspian coastal areas. They develop mainly under irrigated conditions and are characterized by relatively low humus content (1.5-2.2%), predominantly light-clayey, silty and dusty texture, and an alkaline reaction (pH 8.0-9.5). Carbonates occur throughout the soil profile. The vegetation of grey soils is dominated by drought- and salt-tolerant ephemeral, ephemeroid, and xerophytic species. The principal plants include *A. fragrans*, *A. lerchiana*, *S. nodulosa*, *S. dendroides*, *A. pseudalhagi*, *C. aphyllum*, *S. altissima*, *H. strobilaceum*, and *A. cana*. Ephemeral species include *Bromus tectorum*, *H. leporinum*, and *A. fatua*. In locally wetter environments, *Phragmites australis* and *Tamarix ramosissima* may also occur. The predominance of xerophytic and halophytic species reflects adaptation to low soil organic matter, carbonate-rich conditions, periodic moisture deficit, and, in some areas, salinity.

Meadow-grey soils (Cambisols) are mainly distributed in the Kura-Araz Lowland and occur locally in the Samur-Devechi lowlands. They develop predominantly under subtropical semi-desert conditions, where mean annual air temperature is approximately 12.5-14.6°C and annual precipitation ranges from about 215 to 310 mm. The cultivated horizons generally have a dusty-cloddy to cloddy-granular structure. Irrigated meadow-grey soils commonly exhibit signs of salinity and gleying, while their particle-size composition is relatively heavy and dominated by silt particles. Humus content in the plough horizon ranges from approximately 1.3 to 2.8%, and carbonates occur throughout the soil profile.

The vegetation represents a transition between semi-desert and meadow communities and therefore includes both xerophytic and mesophytic species. Characteristic plants include *A. lerchiana*, *A. fragrans*, *A. pseudalhagi*, *S. nodulosa*, *E. repens*, *Poa pratensis*, *B. inermis*, *Trifolium pratense*, *Hordeum leporinum*, and *Carex* spp. In wetter sites, *P. australis* and *T. ramosissima* are also found, whereas halophytic species such as *Suaeda altissima* and *Atriplex cana* occur locally. Thus, the vegetation reflects the transitional moisture conditions of these soils, combining drought tolerance with adaptation to relatively moist and, locally, saline environments.

Alluvial-meadow soils (Fluvisols) are widely distributed in river valleys, floodplains, and areas where groundwater occurs relatively close to the soil surface. In Azerbaijan, they are associated particularly with the floodplains of the Kura and Araz rivers and their tributaries, as well as with the Lankaran and Guba-Khachmaz lowlands. These soils develop mainly from recent stratified alluvial deposits composed of sandy-loamy and sandy-gravelly sediments. Their particle-size distribution is highly variable and includes clayey, heavy-loamy, and loamy varieties. Humus content in the upper horizons ranges from approximately 2.6 to 5.3% and gradually decreases with depth to about 0.5-1.2%. The soil reaction is generally weakly alkaline, although the original source data indicate variability in pH. Most profiles are not saline, but weakly saline forms occur locally.

The relatively high humus content and favourable moisture regime support meadow, marsh, and hygrophilous vegetation. The principal species include *P. australis*, *Typha latifolia*, *Trifolium pratense*, *E. repens*, *P. pratensis*, *B. inermis*, *Phleum pratense*, *Mentha aquatica*, *Petasites hybridus*, *Carex* spp., *T. ramosissima*, *Salix alba*, and *Populus alba*. The occurrence of these species is associated with relatively favourable soil-moisture conditions and shallow groundwater. The observed plant communities are consistent with the ecological differentiation of vegetation described in regional geobotanical studies (Gurbanov & Jabbarov, 2017).

Meadow-marsh soils (Gleysols) are distributed mainly around coastal marshes and depressions of the Lankaran and Kura-Araz lowlands. They develop under excessive groundwater and surface-water moisture, commonly beneath reed-sedge and meadow-marsh vegetation. Groundwater is generally found at depths of approximately 0.5-1.0 m and may reach the soil surface during spring. The parent materials are predominantly silty-clayey and heavy-loamy deposits. These soils are characterized by pronounced gleying and may locally show carbonate accumulation and salinity. Their texture is generally very heavy, while humus content is relatively low (1.2-2.0%). Seasonal fluctuations in groundwater depth are considerable, and gley features may occur at approximately 1.0-1.5 m depth. The vegetation is dominated by hydrophytic and hygrophytic species adapted to prolonged waterlogging and poor soil aeration.

The main species include *P. australis*, *T. latifolia*, *Carex* spp., *Scirpus lacustris*, *Mentha aquatica*, *Glyceria maxima*, *Iris pseudacorus*, *Alisma plantago-aquatica*, *Lotus uliginosus*, *Butomus umbellatus*, *T. ramosissima*, and *S. alba*. Their occurrence reflects adaptation to high soil moisture, reduced oxygen availability, and periodically saturated soil conditions.

Marsh soils (Histosols) remain permanently or for prolonged periods under excessive moisture and are therefore characterized by hydrophytic and hygrophytic vegetation. Low oxygen availability and the accumulation of organic residues favour organic-matter accumulation and, under suitable conditions, peat formation. The main plant species associated with marsh soils include *P. australis*, *T. latifolia*, *Carex* spp., *S. lacustris*, *G. maxima*, *I. pseudacorus*, *A. plantago-aquatica*, *Marsilea quadrifolia*, *Mentha aquatica*, *Butomus umbellatus*, *Nymphaea alba*, *Lemna minor*, and, in acidic marshes, *Drosera rotundifolia*. Mosses, particularly *Sphagnum* spp., may also occur. Woody vegetation includes *S. alba*, *Alnus glutinosa*, and *T. ramosissima*.

In Azerbaijan, marsh soils are mainly associated with the Lankaran Lowland, humid areas of the Kura-Araz Lowland, lakes and lagoons, and Caspian coastal marshes. The vegetation is adapted to waterlogged conditions, poor aeration, and prolonged soil saturation. These ecosystems contribute to biodiversity conservation, carbon sequestration, and the provision of habitats for aquatic and terrestrial organisms. Saline soils (Solonchaks) (Figure 4). The development and distribution of Solonchaks are strongly influenced by hydrogeological conditions, groundwater mineralization, groundwater regime, and the nature of the underlying parent materials. In strongly saline soils, soluble salts may accumulate in the surface horizons, where a characteristic salt crust can develop. The vegetation of saline soils is generally sparse and dominated by halophytic species capable of tolerating high salt concentrations. Characteristic plants include *Halocnemum strobilaceum*, *S. dendroides*, *S. nodulosa*, *S. altissima*, *Salicornia europaea*, *T. ramosissima*, *A. cana*, *Petrosimonia brachiata*, *Limonium meyeri*, *A. pseudalhagi*, and *Calligonum aphyllum*. In wetter saline habitats, *P. australis* and *T. latifolia* may also occur.

Saline soils are widespread in the Kura-Araz Lowland, Absheron Peninsula, Mughan and Shirvan plains, and low-lying Caspian coastal areas. Many halophytes possess succulent tissues or other physiological adaptations that allow them to tolerate high salt concentrations. The dominance of halophytes demonstrates the strong influence of soil salinity on plant-community composition. Recent research on the Caspian coast of Azerbaijan has also emphasized the ecological importance of halophytes in maintaining ecosystem stability under salinity, sea-level fluctuations, and anthropogenic pressure (Gurbanov & Huseynova, 2026)



Figure 4. Saline and Solonchak soils

Takyr-like soils are characterized by a compact, clayey and relatively smooth surface, with sparse or locally absent vegetation. They occur locally in southeastern Shirvan and the Siyazan–Sumgait area. Considerable quantities of readily soluble salts may accumulate beneath the surface crust, which is typically fragile and cracked. The associated vegetation is sparse and consists mainly of drought- and salt-tolerant species, including *Artemisia lerchiana*, *Salsola nodulosa*, *Suaeda altissima*, *Halocnemum strobilaceum*, *Atriplex cana*, *Alhagi pseudalhagi*, *Calligonum aphyllum*, *Limonium meyeri*, *Petrosimonia brachiata*, and *Calligonum bakuense*. Ephemeral species such as *Hordeum leporinum*, *Bromus tectorum*, and *Avena fatua* may occur during favourable

moisture periods. The sparse vegetation reflects the combined effects of surface crusting, limited water availability, and salinity.

Sandy coastal soils (Arenosols) develop mainly on coastal and near-coastal sandy landforms shaped by marine processes and wind activity (Figure 5). Their low humus content, weak water-holding capacity, and high permeability create strong environmental constraints for plant growth. Consequently, the vegetation is dominated by psammophytic and xerophytic species adapted to drought, wind exposure, and unstable sandy substrates. Characteristic species include *C. aphyllum*, *A. arenaria*, *E. giganteus*, *L. racemosus*, *C. maritima*, *C. arenaria*, *S. kali*, *M. marina*, *C. bakuense*, *A. cana*, and *S. europaea*. In wetter depressions and locally moist parts of the coastal zone, *P. australis* and *T. ramosissima* may also occur.

The main ecological adaptations of these plants include extensive root systems that stabilize sand, tolerance to drought and salinity, reduced water loss through narrow or succulent leaves, and resistance to wind erosion. Sandy coastal soils are mainly distributed along the Caspian coast, particularly on the Absheron Peninsula, Samur-Devechi coastal zone, Kura Spit, and other accumulative coastal plains. The presence of specialized psammophytic species reflects the importance of substrate properties in determining coastal plant distribution, consistent with relationships reported for the Caspian coastal zone (Dimeyeva, 2013).



Figure 5. Sandy coastal soils

Hydromorphic soils (Gleysols) occur mainly in poorly drained areas of the Kura–Araz Lowland and along the Caspian coast (Figure 6). They develop under conditions of excessive moisture and a shallow groundwater table, commonly influenced by mineralized groundwater. Groundwater may occur at depths of approximately 0.5-1.5 m, while readily soluble salts may accumulate within the upper 20-30 cm and deeper horizons.

The vegetation of hydromorphic soils is strongly controlled by both moisture and salinity. In non-saline or weakly saline sites, hydrophytic and hygrophytic species such as *P. australis*, *T. latifolia*, *Carex* spp., *S. lacustris*, *G. maxima*, *M. aquatica*, *A. plantago-aquatica*, *I. pseudacorus*, *B. umbellatus*, *N. alba*, and *L. minor* predominate. Woody species include *S. alba*, *P. alba*, *Alnus glutinosa*, and *T. ramosissima*. Where salinity is pronounced, halophytes such as *Suaeda altissima*, *S. dendroides*, and *Halocnemum strobilaceum* become more prominent.

The predominance of halophytic species in saline hydromorphic environments indicates the combined influence of groundwater conditions and soil salinity on vegetation structure. In contrast, non-saline hydromorphic soils support more diverse hydrophytic and hygrophytic communities. Thus, vegetation composition provides a clear ecological indication of the combined effects of soil moisture regime, groundwater depth, aeration, and salinity in the Caspian coastal landscapes. Recent phytosociological research in Azerbaijan has demonstrated considerable diversity of aquatic and halophytic plant communities. Atamov & Musayev (2026) identified numerous plant associations associated with aquatic, wetland, and saline habitats, supporting the observed differentiation of vegetation under contrasting moisture and salinity conditions.



Figure 6. Waterlogged and hydromorphic coastal soils

Soil Types and Associated Plant Species

The soil types distributed in the Caspian coastal areas of Azerbaijan and the plant species characteristic of each soil type are presented in the Table 1. The predominance of halophytes demonstrates the strong influence of soil salinity on plant-community composition. Recent research on the Caspian coast of Azerbaijan emphasizes the ecological role of halophytes in saline coastal systems and their importance for maintaining ecosystem stability under conditions of salinity, sea-level fluctuations, and anthropogenic pressure (Gurbanov & Huseymova, 2026). The presence of specialized psammophytic species reflects the importance of substrate properties in determining coastal plant distribution. Similar relationships between substrate conditions and plant communities have been described for the Caspian coastal zone (Dimeyeva, 2013). Overall, the observed distribution confirms that soil salinity, moisture regime, and substrate characteristics are major factors controlling the composition of coastal vegetation. The presence of specialized halophytes on saline soils and hydrophytic species on wet soils demonstrates the close relationship between edaphic conditions and ecological plant groups.

Plant Biodiversity of the Caspian Coastal Areas

Examples of plants occurring on saline, marshy, alluvial, and sandy soils in the Caspian coastal areas are presented in Figures 10-12. The flora of the Caspian coast is highly dynamic, and its composition is determined by the balance of soil moisture and salts, as well as by soil texture (Dimeyeva, 2013). Numerous ponds, oxbow lakes, and wetland areas occur in the Caspian coastal regions and the Kura–Araz Lowland. These habitats support psammophytic, littoral, and wetland vegetation, as well as intrazonal desert and semi-desert communities and meadow vegetation developing in waterlogged areas (Gurbanov & Jabbarov, 2017).

The studied coastal landscapes support diverse plant communities associated with saline, sandy, alluvial, meadow, marsh, and hydromorphic environments. The flora includes species with different ecological adaptations, from highly salt-tolerant halophytes to hydrophytic, mesophytic, xerophytic, and psammophytic species. The southern part of the Caspian coast of Azerbaijan is also characterized by considerable floristic diversity. Huseynova (2023) documented new distribution areas of several plant species in the southern Caspian coastal zone, demonstrating the continuing importance of these habitats for regional plant diversity. The presence of rare and subendemic plants increases the conservation value of the coastal flora. Huseynova & Shah (2023) reported considerable subendemic plant diversity along the Caspian coastal flora of Azerbaijan and emphasized the importance of conserving specialized coastal habitats.

The observed vegetation mosaic therefore reflects both the diversity of soil conditions and the ecological specialization of individual plant species. Halophytes such as *Salicornia europaea*, *Halocnemum strobilaceum*, *Suaeda altissima*, *Atriplex cana*, and *Petrosimonia brachiata* are associated mainly with saline habitats, whereas *Phragmites australis*, *Typha latifolia*, *Carex* spp., and other moisture-dependent species characterize hydromorphic and wetland environments. Some plants distributed in the Caspian coastal areas are given in the figure (Figure 7, 8, 9).

Table 1. Soil types and associated plant species distributed in the Caspian Coastal areas of Azerbaijan

No.	Soil type	WRB Reference Soil Group	Representative plant species
1	Grey-brown soils	Calcisols	<i>Artemisia</i> spp., <i>A. maurorum</i> , <i>Salsola</i> spp., <i>Suaeda dendroides</i> , <i>Aeluropus littoralis</i> , <i>C. aphyllum</i> , <i>Rumex crispus</i> , <i>E.repens</i> , <i>Cynodon dactylon</i> , <i>Capparis spinosa</i> , <i>Bromus</i> spp., <i>Poa</i> spp., <i>Eremopyrum</i> spp.
2	Grey soils	Calcisols	<i>A.fragrans</i> , <i>A. lerchiana</i> , <i>S. nodulosa</i> , <i>S. dendroides</i> , <i>A. pseudalhagi</i> , <i>C. aphyllum</i> , <i>Suaeda altissima</i> , <i>H.strobilaceum</i> , <i>A. cana</i> , <i>B. tectorum</i> , <i>Hordeum leporinum</i> , <i>Avena fatua</i> , <i>P. australis</i> , <i>T. ramosissima</i>
3	Meadow-grey soils	Cambisols	<i>A.lerschiana</i> , <i>A. fragrans</i> , <i>A. pseudalhagi</i> , <i>S. nodulosa</i> , <i>E.repens</i> , <i>P. pratensis</i> , <i>B.inermis</i> , <i>Trifolium pratense</i> , <i>H. leporinum</i> , <i>Carex</i> spp., <i>P. australis</i> , <i>T. ramosissima</i> , <i>S.altissima</i> , <i>A. cana</i>
4	Alluvial-meadow soils	Fluvisols	<i>P.australis</i> , <i>Typha angustifolia</i> , <i>Carex melanostachya</i> , <i>Juncus maritimus</i> , <i>E. repens</i> , <i>P.pratensis</i> , <i>Trifolium pratense</i> , <i>B. inermis</i> , <i>P. pratense</i> , <i>Carex</i> spp., <i>T. latifolia</i> , <i>S. alba</i> , <i>P. alba</i> , <i>Alnus glutinosa</i> , <i>T. ramosissima</i> , <i>Elaeagnus angustifolia</i> , <i>S. altissima</i> , <i>S. dendroides</i>
5	Meadow-marsh soils	Gleysols	<i>P. australis</i> , <i>T. latifolia</i> , <i>Carex</i> spp., <i>S. lacustris</i> , <i>M. aquatica</i> , <i>G. maxima</i> , <i>I. pseudacorus</i> , <i>A. plantago-aquatica</i> , <i>L. uliginosus</i> , <i>B.umbellatus</i> , <i>T. ramosissima</i> , <i>S. alba</i>
6	Marsh soils	Histosols	<i>P. australis</i> , <i>T. latifolia</i> , <i>Carex</i> spp., <i>S. lacustris</i> , <i>G. maxima</i> , <i>I. pseudacorus</i> , <i>A. plantago-aquatica</i> , <i>Marsilea quadrifolia</i> , <i>M. aquatica</i> , <i>B. umbellatus</i> , <i>Nymphaea alba</i> , <i>Lemna minor</i> , <i>Drosera rotundifolia</i> , <i>Sphagnum</i> spp., <i>S. alba</i> , <i>Alnus glutinosa</i> , <i>T. ramosissima</i>
7	Saline soils	Solonchaks	<i>Halocnemum strobilaceum</i> , <i>S. dendroides</i> , <i>S. nodulosa</i> , <i>S. altissima</i> , <i>Salicornia europaea</i> , <i>T. ramosissima</i> , <i>Atriplex cana</i> , <i>Petrosimonia brachiata</i> , <i>Limonium meyeri</i> , <i>A. pseudalhagi</i> , <i>A.lerschiana</i> , <i>Calligonum aphyllum</i> , <i>P. australis</i> , <i>T. latifolia</i>
8	Takyr-like soils	Solonchaks / Solonetz	<i>A. lerchiana</i> , <i>S.nodulosa</i> , <i>S.altissima</i> , <i>H. strobilaceum</i> , <i>A. cana</i> , <i>A.pseudalhagi</i> , <i>C.aphyllum</i> , <i>L.meyeri</i> , <i>P. brachiata</i> , <i>C.bakuense</i> , <i>H.leporinum</i> , <i>B.tectorum</i> , <i>A.fatua</i>
9	Sandy coastal soils	Arenosols	<i>C. aphyllum</i> , <i>A.arenaria</i> , <i>E. giganteus</i> , <i>P. australis</i> , <i>T. ramosissima</i> , <i>A.pseudalhagi</i> , <i>Leymus racemosus</i> , <i>Cakile maritima</i> , <i>C. arenaria</i> , <i>S. kali</i> , <i>S. altissima</i> , <i>Medicago marina</i> , <i>C. bakuense</i> , <i>A. cana</i> , <i>Salicornia europaea</i>
10	Hydromorphic soils	Gleysols	<i>P.australis</i> , <i>T. latifolia</i> , <i>Carex</i> spp., <i>S. lacustris</i> , <i>G.maxima</i> , <i>Mentha aquatica</i> , <i>A. plantago-aquatica</i> , <i>I. pseudacorus</i> , <i>B.umbellatus</i> , <i>Nymphaea alba</i> , <i>L.minor</i> , <i>S. alba</i> , <i>Populus alba</i> , <i>A.glutinosa</i> , <i>T. ramosissima</i> , <i>S. altissima</i> , <i>S. dendroides</i> , <i>H. strobilaceum</i>



Figure 7. Tamarisk (*Tamarix ramosissima*)



Figure 8. European glasswort (*Salicornia europaea*)



Figure 9. Common reed (*Phragmites australis*)

Implications for Biodiversity Conservation

The results indicate that soil diversity is closely associated with plant diversity in the Caspian coastal landscapes of Azerbaijan. Saline soils support specialized halophytic and xero-halophytic communities, sandy soils provide habitats for xerophytic and psammophytic species, while alluvial and hydromorphic soils support more diverse meadow, riparian, and wetland vegetation. Coastal ecosystems are vulnerable to soil degradation, salinization, pollution, urbanization, changes in hydrological conditions, and fluctuations in Caspian Sea level. On the Absheron Peninsula, degradation and contamination of soils associated with industrial and oil-production activities represent an important environmental problem (Aslanov, 2005; Aslanov & Safarli, 2008; Mamedov & Guliyev, 2009).

Changes in the hydrological and climatic regime may further modify soil moisture and salinity and consequently influence plant-community composition. The cumulative effects of environmental pressures on the Caspian ecosystem have been documented in recent studies (Bodini et al., 2024; Lahijani et al., 2024). The conservation of coastal biodiversity therefore requires integrated monitoring of soil and vegetation conditions. Particular attention should be given to saline habitats containing specialized halophytes, wetland and hydromorphic ecosystems, sandy coastal habitats, alluvial landscapes, and areas supporting rare and

subendemic plant species. Strengthening pollution monitoring and biodiversity planning is also identified as an important priority for the Caspian region (UNOPS, 2026).

4. CONCLUSIONS

The study demonstrated considerable soil and plant diversity in the Caspian coastal and near-coastal territories of Azerbaijan, including the Absheron Peninsula, Lankaran region, Kura-Araz Lowland, and Samur-Devechi Lowland. The results showed a clear relationship between soil conditions and vegetation composition. Saline soils were mainly associated with halophytic and xero-halophytic species, while hydromorphic and wetland soils supported predominantly hydrophytic and hygrophilous vegetation. Sandy coastal soils were characterized mainly by xerophytic and psammophytic species, whereas alluvial soils supported diverse meadow, riparian, herbaceous, and woody vegetation. Takyr-like soils were mainly occupied by drought- and salt-tolerant plants.

The study confirms that soil diversity is an important factor determining plant biodiversity in the Caspian coastal zone. Soil salinity, moisture regime, groundwater conditions, texture, and substrate characteristics act as important ecological factors controlling plant-community composition. Increasing anthropogenic pressure, soil degradation, pollution, and changes in hydrological conditions may threaten vulnerable coastal ecosystems. Therefore, integrated monitoring of soil and vegetation, conservation of saline, wetland, sandy, and alluvial habitats, and sustainable management of coastal ecosystems are recommended.

AUTHOR CONTRIBUTIONS

NO: Conceptualization, Methodology, Investigation, Writing – Original Draft; UM: Formal Analysis, Visualization, Project Administration, Writing – Review & Editing; BS: Data Curation, Writing – Original Draft; IK: Supervision, Writing – Review & Editing; SM: Writing – Original Draft, Writing – Review & Editing; YM: Writing – Original Draft, Writing – Review & Editing.

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The authors declare no conflicts of interest.

AI DECLARATION

No artificial intelligence tool generated primary research data

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