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Soil Characteristics and Vegetation Patterns in the Arid Steppe Rangeland in Southeast Algeria (Biskra)

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Abstract

This study aims to characterize soil properties, climate change and to investigate how these parameters influence the distribution of vegetation in the arid rangeland of Biskra (Algeria). Soil samples were collected from three stations in El-Haouch city. Physicochemical soil parameters were analysed in each phytoecological group of rangeland type. Relationships between soil traits were tested to determine spatial variation and their effects on arid rangeland. Furthermore, the influence of pedological factors on the distribution and establishment of vegetation was examined using redundancy analysis (RDA). The Mann-Kendall and Pettitt trend tests were used to analyse the climate data. The observed climate trends showing significant changes from 1987 to 2019 include a considerable decrease in annual rainfall and an increase in temperature. RDA showed that soil parameters that best explained the vegetation distribution were EC, pH, organic matter (OM), $CaCO_3$, and soil texture. Atriplex halimus and Suaeda vermiculata in Salty depressions grew under higher soil salinity (EC = 10.2 mS/cm) compared to Retama retam and Thymelaea microphylla, which tolerate moderate soil salinity with low organic matter. Atriplex halimus and Tamarix gallica in Wadi beds grew in soils characterized by high pH values but relatively low in OM. Additionally, low organic matter content, high salinization, and anthropogenic pressures, such as overgrazing and agricultural expansion, further increase the vulnerability of these arid steppe ecosystems to degradation. These findings highlight the need for sustainable land management strategies to mitigate environmental stress and preserve steppe biodiversity.

Keywords: *Soil Parameters, Arid Rangeland. Physicochemical Parameters, Climate Change, Degradation.*

1. INTRODUCTION

The steppe ecosystem is the second-largest and most significant land ecosystem in the world, covering approximately 40% of the Earth's terrestrial surface (Suttie et al., 2005). It provides multiple human goods and services, including economic services such as food, fiber,

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

medicine, energy, and animal feed, as well as nonmaterial services such as climate regulation, soil erosion control, leisure tourism, and ethno-cultural inheritance (Sala et al., 2017; Peng et al., 2020; Dong et al., 2020). Steppe rangeland degradation has been more widely observed in recent years and has become an increasingly serious problem in certain areas (Abdalla et al., 2018; Harris, 2010; Liu et al., 2018; Robinson Li & Hou 2017; Schonbach et al., 2011; Wei et al., 2020; Zhang et al., 2014).

The Algerian steppes, situated between the Tellian Atlas in the north and the Saharan Atlas in the south, encompass more than 20 million hectares. They are limited to the North by the 500 mm isohyet, which coincides with the extension of dry cereal crops, and to the South by the 100 mm isohyet, which represents the southern limit of the extension of esparto (*Stipa tenacissima*). Ecologically, the steppe regions constitute a buffer between coastal Algeria and Saharan Algeria, limiting the negative climatic influences on the former (Oubadi et al., 2024). This rangeland is a fragile ecosystem very sensitive to degradation, which is caused by environmental factors (desertification, climate change, and drought), and socio-economic factors (over-grazing and poor management) (Aidoud, 1996; Belala et al., 2018; Belhadj et al., 2023a; Merdas et al., 2019; Moulay et al., 2011; Nedjraoui & Bedrani, 2008; Slimani et al., 2010). The soils in this rangeland are characterized by the presence of limestone accumulation and low organic matter content, with good forage values represented by psammophilic and halophilic species (Nedjraoui & Bédrani, 2008). In Algeria, extensive research has documented the progressive degradation of soil and vegetation cover in rangelands over the past four decades (Neffar et al., 2018; Boudjabi & Chenchouni, 2022) and can lead to a desertification of steppe ecosystems (Amghar et al., 2016).

The present study aims to describe edaphic patterns of vegetation in the arid rangeland of El-Haouch, Biskra (Algeria), and to determine if soil properties and climate change tend to influence that distribution. Besides, this survey provides a soil characterization through physicochemical analyses and examines spatial patterns and variations of soil traits as well as their interactions to simplify the understanding of relationships between soil characteristics and the distribution of rangeland vegetation in arid areas.

2. MATERIALS AND METHODS

2.1 Study area

The study area, El-Haouch, is situated south of Biskra, at a latitude of 34°33'43" N and a longitude of 06°03'05" E (Fig. 01). From the geological point of view, the study area is composed mainly of Continental Quaternary, Continental Pliocene, and Current alluvium. Hydrologically, the El-Haouch region is primarily fed by Oued Biskra, Oued Boulabes, and Oued Djedi, which are alimented by the Aurès Rivers. Subsequently, the Oued flows into the Chott Melghir basin (Belhadj et al., 2023 b).

The landscape is characterised by vast alluvial fans and a plain modelled by wadi courses, with their source areas in the Atlas and eventually fading into the great depression of the greater watershed of Chott Melghir, which reaches an average of -80 m below sea level (Afrasinei et al., 2015). The study area is located at an altitude between 17 m and -18 m and exhibits moderate topographic slopes ranging from <5% to 30%. (Fig. 01). Classified as an arid zone (Belhadj et al., 2023b), El-Haouch experiences low and irregular annual precipitation (152 mm) and prolonged periods of drought. Winter temperatures can drop to 7°C, while summer temperatures frequently exceed 40°C in July and August (MSB 2019). Monthly precipitation

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

and temperature data (1987 – 2019) were obtained from the Biskra meteorological station (Long. 5.738° E; Lat. 34.793° N; Alt. 88 m). This station, located at the Biskra airport, is part of the Algerian National Meteorological Office network and provides comprehensive and reliable climatic data essential for regional environmental and ecological studies. A study conducted by Belhadj et al. (2023a) was carried out using a floristic inventory. Our study focused on short-term monitoring of arid steppe rangelands in southeastern Algeria (El-Haouch). Three sites were selected for investigation (the same sites were used for soil sampling) (Fig. 1): site 1 (altitude = 17 m), site 2 (altitude = 11 m), and site 3 (altitude = –18 m). Phytoecological sampling was conducted monthly during 2017 and 2018 using a simple subjective sampling method. In total, 216 samples were collected from floristically homogeneous and representative areas, each with a minimum surface area of 100 m² (10 m × 10 m), according to (Djebaili, 1984; Chalane, 2012; Yahiaoui, 2011; Arabi et al., 2015; Amrani, 2021).

A total of **24 species** belonging to **13 families** were identified, with a predominance of **perennial (P)** species over **annual (A)** forms. The **Chenopodiaceae** family was the most represented, including several halophytic species such as *Atriplex halimus*, *Anabasis articulata*, and *Suaeda vermiculata*, which were particularly abundant at the saline and wadi sites. *Atriplex halimus* and *Tamarix gallica* exhibited strong dominance in both years, especially at Site 1 (wadi rangeland) and Site 3 (saline rangeland). In contrast, Site 2 (sandy soils) supported characteristic **psammophytic taxa**, notably *Retama raetam* and *Thymelaea microphylla*. (Appendix)

Three sites, labeled WR, SR, and SalR, were selected along a study area for soil sampling and measurement of physicochemical characteristics (Table 01).

The first site represents rangeland established on Wadi beds (WR), while the second occurs on sandy soils (SR), and the third site is characterized by rangeland in saline accumulation (SalR).

Site #1: represents rangeland established on Wadi beds at an altitude of 17 m, comprising 17 species from 10 botanical families. This site is characterized by a relatively high species richness, reflecting the more favorable moisture conditions typically found in wadi beds. The dominant species, *Atriplex halimus* and *Tamarix gallica*, indicate the presence of arid conditions with intermittent water availability, with a mean vegetation cover of 15.80±5.32 and 16.33±5.41, respectively, in 2017/2018; 2018/2019 (Table 01). The specific richness values recorded were 3.11 ± 0.99 and 2.77 ± 2.37 for the same periods, respectively. The vegetation structure suggests adaptation to occasional flooding events and temporary water retention, supporting both halophytic and xerophytic elements.

Site #2: located at an altitude of **11 m**, occurs on sandy soils and includes 8 species from 6 families. It is characterized by psammophytic vegetation dominated by *Retama raetam* and *Thymelaea microphylla*, species that are well adapted to loose, nutrient-poor, and highly drained substrates. These plants are typical of aeolian formations, where wind action shapes both the soil and the vegetation structure. The sparse cover and specialized root systems reflect adaptations to sand mobility, drought stress, and limited water-holding capacity, with a mean vegetation cover of 12.80±2.94 (2017/2018) and 12.92±4.04 (2018/2019). While the specific richness values recorded were 1.30 ± 1.61 and 2.13 ± 1.45 for the same periods, respectively, in Table 01.

GRADIVA

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

Site #3: situated at an altitude of –18 m near Chott Melghir, is characterized by saline accumulations, with vegetation dominated by *Atriplex halimus* and *Suaeda vermiculata*, the mean vegetation cover is 12.66±2.49 in (2017/2018), and 14.55±2.15 in (2018/2019) (Table 1). This site includes 9 species from 4 families, mainly halophytic taxa capable of tolerating high salinity levels. The specific richness values recorded were 1.50 ± 1.59 and 2.61 ± 1.29 for the periods (2017/2018; 2018/2019), respectively (Table 01). The dominance of salt-tolerant shrubs indicates strong edaphic control, where soil salinity governs species distribution and plant community composition. The vegetation is typically low and sparse, representing a halophytic rangeland ecosystem influenced by the proximity to the saline depression. (Fig. 01).

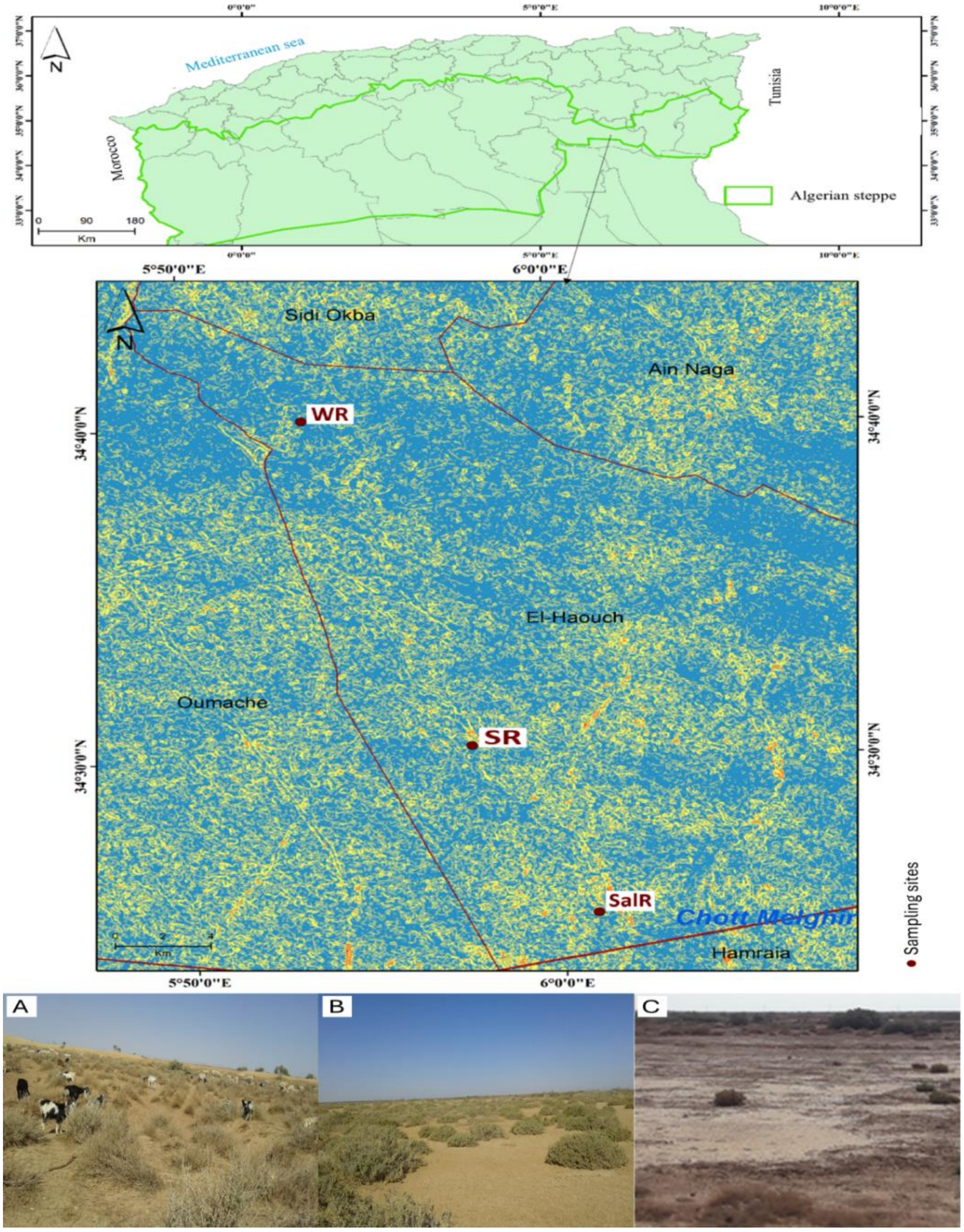

Figure 01: Geographic location of soil survey sites in the El-Haouch region, "Southeast Algeria (Biskra)"; (WR) Wadi beds; (SR) Sandy soils, (SalR) Saline accumulation, (A); Rangelands in Wadi beds, (B); Rangelands in Sandy soils, (C); Rangelands in saline accumulation

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

Table 01: Characteristics of Wadi beds (WR), sandy soils (SR), and the saline accumulation (SalR) in sampling sites of southeastern Algeria, Biskra (El-Haouch)

Characteristics	Study rangeland sites					
	wadi beds (WR)		sandy soils (SR)		saline accumulation (SalR)	
	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Dominant plant species	*Atriplex halimus* and *Tamarix gallica*		*Retama retam* and *Thymelaea microphylla*		*Atriplex halimus* and *Suaeda vermiculata*	
Altitude	17 m		11 m		-18 m	
Total vegetation cover (%)	15.80±5.32	16.33±5.41	12.80±2.94	12.92±4.04	12.66±2.49	14.55±2.15
Species richness	3.11±0.99	2,77±2.37	1.30±1.61	2.13±1.45	1.5±1.59	2.61±1.29

2.2 Soil sampling

Given the strong heterogeneity of the study area, characterized by distinct geomorphological units such as Wadi beds (WR), sandy soils (SR), and saline accumulation zones (SalR), a subjective sampling approach represents the most suitable strategy for our research (Gounot, 1969). This method allows targeted selection of sampling sites based on visible environmental characteristics, ensuring that each major landform and its associated ecological conditions are properly represented. By prioritizing landscape features and local homogeneity within each unit, subjective sampling reduces the risk of overlooking key soil–vegetation interactions that may occur across these contrasting areas. Such an approach is particularly relevant in arid rangelands, where sharp spatial variability exists over short distances due to hydrological redistribution, salinization processes, and patchy vegetation cover. Consequently, the sampling strategy enhances the accuracy and ecological relevance of comparisons among the different soil types and land management zones included in the study.

To assess the relationships between soil physicochemical properties and the spatial distribution of vegetation in an arid steppe rangeland ecosystem, 90 randomly selected plots were sampled during the spring of 2017/2018 and 2018/2019. This comprised 30 surveys conducted within the Wadi beds site (WR) and 30 surveys conducted in sandy soils (SR), and 30 surveys in the saline accumulation (SalR) (Fig. 01).

The coarse elements consist of the coarse fraction of the soil, specifically gravel, pebbles, stones, and blocks, which have a grain diameter exceeding 2 mm (Baize & Jabiol, 2021). These elements are formed from the disintegration of the source rock due to physical, chemical, and biological processes (Baize, 2018).

Soil samples were collected from profiles to a depth of 30 cm using a pickaxe. A total of ninety (90) soil samples, consisting of three replicates; 30 samples from WR (15 samples during the 2017/2018 and 15 samples during the 2018/2019), 30 samples from SR (15 surveys in 2017/2018 and 15 surveys in 2018/2019), and 30 samples from SalR (15 samples in 2017/2018 and 15 samples in 2018/2019)), were collected in labeled paper bags containing the corresponding sample information. The samples were air-dried for 10 to 15 days and subsequently sieved through a 2 mm mesh to separate the coarse elements (Ø > 2 mm) from the fine earth (Ø < 2 mm) (Macheroum & Chenchouni, 2022).

2.3 Soil analysis

Soil samples were open-air dried and then sieved using a mesh size of < 2mm. The fine earth obtained was used to determine the following standard physical and chemical soil parameters (Baize, 2000; Pansu & Gautheyrou, 2006). Grain size was obtained using a

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

Robinson pipette, which determines rates of clay and fine silt. Coarse and fine sand were measured by sieving. The coarse silt fraction was calculated from previous results (Baize, 2000). The grain size analysis was reported according to the percentages of clay, silt, and sand in the textural triangle to determine soil textural classes, which follow the USDA classification of soil textures (Soil Survey Staff, 2014);

The electrical conductivity (EC) was measured using saturated paste extracts at 25 °C (Hu et al., 2014).

pH was measured using a pH meter in a soil suspension with a soil/ water ratio of 1/2.5 (Pansu & Gautheyrou, 2006). Soil organic matter (SOM) in % was calculated from the soil organic carbon (SOC) content (SOM = SOC × 1.724), which was quantified using the Walkley-Black method (Baize 2018). Total Limestone ($CaCO_3$) was determined using the volumetric method with Bernard's calcimeter. Calcium carbonates were decomposed using hydrochloric acid (HCl), and the released CO_2 volume was measured.

a. Statistical analysis

Descriptive statistics of each soil parameter were represented in boxplots, and the data were analyzed regarding the soil physicochemical properties and plant cover in an arid steppe rangeland ecosystem. The spatial variation of each soil parameter was examined using an analysis of covariance (ANCOVA) following the effects of sites. To understand relationships and trends between physicochemical soil parameters, Pearson correlation tests were performed then the correlation matrix was plotted using the R package "corrplot". Furthermore, to detect gradients in arid rangeland types and species-soil relations, redundancy analysis (RDA) was performed using the "vegan" package in R (R Core Team, 2023). The plotting of the RDA binary plot was performed using a correlative scaling method. The relationships between the soil parameter values of each soil sample and the RDA site scores (weighted sums of species vegetation cover) of the first three RDA axes were tested using Pearson correlation tests. PCA Statistical analyses and models were conducted using R version 4.4.2.

3. RESULTS AND DISCUSSION

3.1 Physicochemical characteristics of soil

The values of EC and $CaCO_3$ displayed similar increasing patterns after the following order of arid rangeland types, which are dominated by the following species: *Atriplex halimus* and *Tamarix gallica* in Wadi beds (WR), *Retama raetam* and *Thymelaea microphylla* in Aeolian formations -Dunes- (SR), *Atriplex halimus* and *Suaeda vermiculata* in Salty accumulations -Depression- (SalR).

Conversely, the contents of organic matter varied in contrast to the trends of the previous parameters. Additionally, the pH values exhibited irregular patterns. Silt values varied between 22.06 and 39.37 %, coarse sand percentage between 27.03 and 33.38 %, fine sand percentage between 17.8 and 35.97 %, and clay value between 7.46 and 15.2 % (Table 02).

The salinity tolerance of arid rangeland species varies significantly, with psammophytes formation (*Retama raetam* and *Thymelaea microphylla*) (SR) exhibiting moderate salinity tolerance (4.53-4.98 mS/cm), salty accumulations formation (SalR) such as *Atriplex halimus* and *Suaeda vermiculata* can withstand much higher salinity levels (9.65-10.56 mS/cm) (Table 2).

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

Table 02: Mean values (±SD) of soil parameters in the arid rangeland in El-Haouch region

Soil Properties	Mean (±SD)		
	Wadi beds	Aeolian formations –Dunes-	Salty accumulations -Depression-
Silt (%)	22.07± 0.05	24.13± 0.09	39.37± 0.19
Coarse sand (%)	33.38± 0.04	33.39± 0.14	27.03± 0.21
Fine sand (%)	35.97± 0.25	31.04± 0.03	17.83± 0.29
Clay (%)	7.46± 0.39	10.09± 0.20	15.2± 0.36
pH	8.49± 0.23	7.25± 0.22	7.56± 0.21
EC (mS/cm)	1.40± 0.10	4.98± 0.24	10.2± 0.48
OM (%)	1.76± 0.06	0.28± 0.06	0.25± 0.03
$CaCO_3$ (%)	29.25± 2.74	32.52± 1.40	22.01± 2.68

This difference highlights the ecological adaptations of these species to their environments. This finding was contrary to the formation in wadi beds, dominated by *Atriplex halimus* and *Tamarix gallica*, which are established on soils with low electrical conductivity (1.3- 1.5 mS/cm). pH values fluctuated between 7.25 and 8.7, with a mean of 8.49 ± 0.23 in Wadi beds and 7.25 ± 0.22 in Aeolian formation -Dunes- (Table 01). The rate of $CaCO_3$ was high and varied between 20.25 and 34.25 %, which qualifies soils in Aeolian formations as rich in active $CaCO_3$, with a mean of 32.52 ± 1.40 (Table 01).

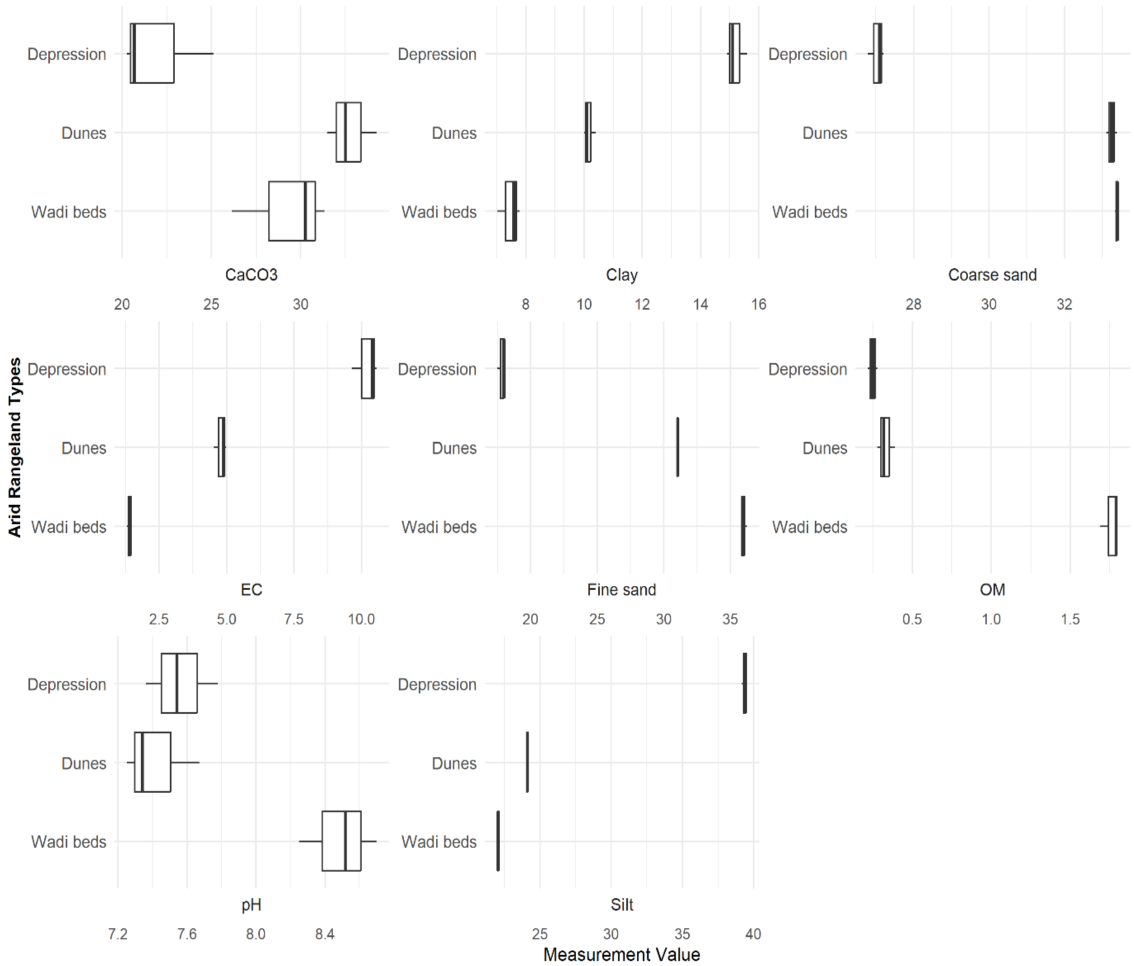

Figure 02: Boxplots displaying the variation of soil variables analysed following arid rangeland types in El-Haouch region. The black line indicates the mean

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

The rate of organic matter varied between 1.8 and 0.22%. Values of OM were higher in soils of Wadi beds occupied by *Atriplex halimus* and *Tamarix gallica*, compared to other rangeland types and species (Fig. 02).

3.2 Soil texture classification

Based on grain size analysis and USDA classification, soil texture was sandy loam in Wadi beds (WR), and sandy soils (SR), and was loam texture in the saline accumulation (SalR) (Fig. 03).

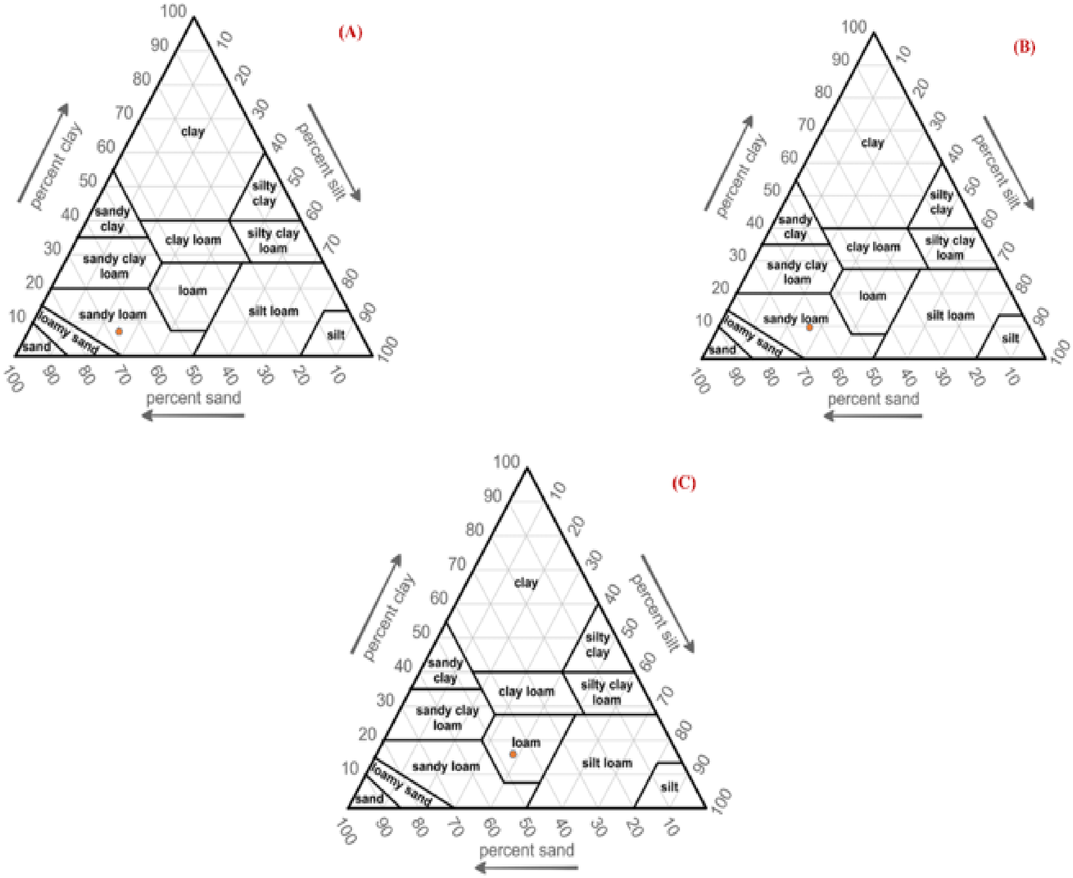

Figure 03: The soil textural triangles following the USDA classification (A); site 1 wadi beds (WR); (B), site 2 sandy soils (SR); (C) site 3 saline accumulation (SalR)

3.3 Spatial variations of soil parameters

3.3.1. Relationships between soil parameters

Among the correlation tests between soil parameters, some were statistically significant ($P < 0.05$). Significant positive correlations were found between OM and pH. Additionally, the correlation between $CaCO_3$ and coarse sand was significantly positive.

Likewise, clay, fine sand, and coarse sand correlate positively with other parameters. Correlation tests revealed that pH was negatively correlated with different parameters ($P > 0.06$). The contents of silt were not related to the values of other parameters (Fig. 04).

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

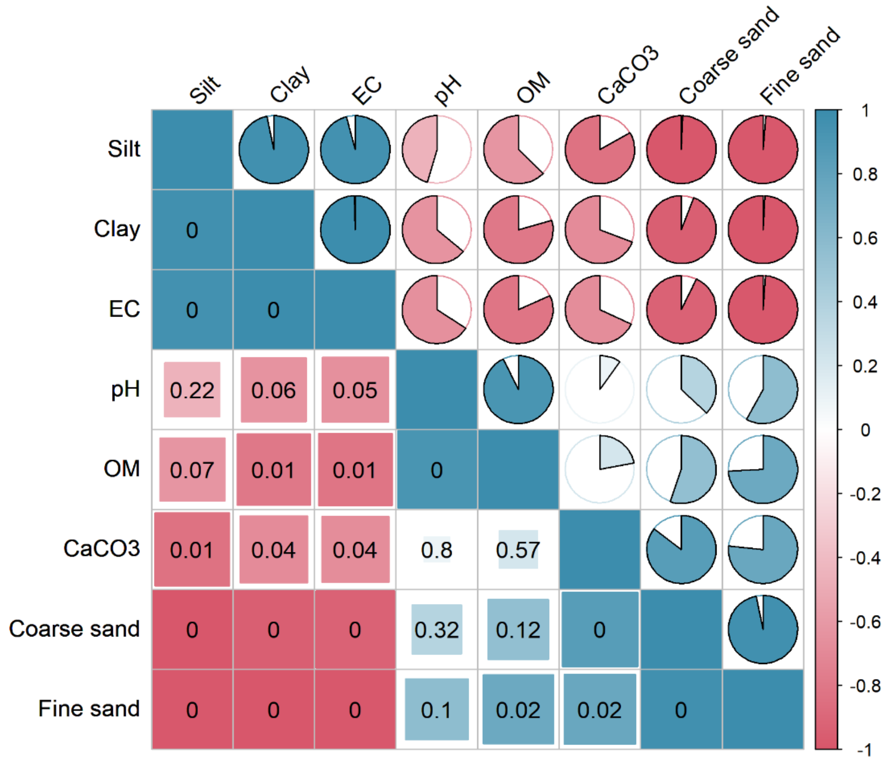

Figure 04: Correlation matrix between soil parameters quantified in arid rangeland types in El-Haouch region

3.3.2. Distribution of arid rangeland types

Redundancy analysis (RDA) allowed the separation of 90 soil samples and 08 pedological variables (soil physicochemical properties) in relation to three sites (WR, SR, and SalR). It explained the inertia by retaining the first two axes with the following eigenvalues: 50 % on RDA dim1 and 50 % on RDA dim2 (Fig. 05).

The partitioning of variance in the RDA analysis determines the relationships between arid rangeland species and soil factor scores. From the intra-set correlations of the soil factors with the axes of Redundancy analyses, $CaCO_3$ was the most significant parameter in axis 1.

OM, pH, coarse sand, and fine sand were positively correlated. According to RDA analysis, the psammophytes formation dominated by *Retama retam* and *Thymelaea microphylla* was positively associated with $CaCO_3$. Rangelands in Wadi beds, dominated by *Atriplex halimus* and *Tamarix gallica*, were positively associated with high levels of pH and OM, but negatively with $CaCO_3$. As far as axis 2, the rangeland located in Wadi beds was positively related to coarse sand and fine sand and negatively associated with silt, and clay (Fig. 05).

The rangeland in the depression (*Atriplex halimus* and *Suaeda vermiculata)* was positively associated with EC, silt, and clay. EC indicated a strong trend of increasing salinity. Aeolian formations -Dunes- (*Retama retam* and *Thymelaea microphylla*) were significantly associated with $CaCO_3$.

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

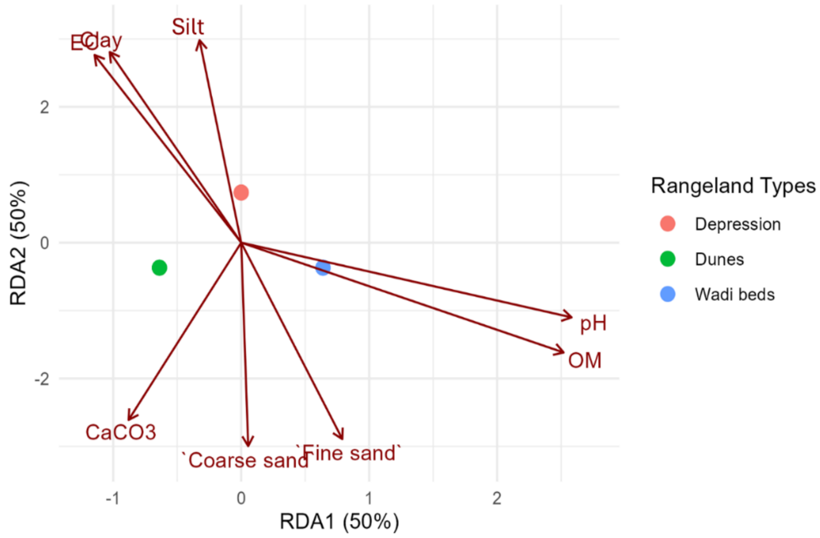

Figure 05: Redundancy analysis (RDA) diagram for the studied soil traits and arid rangeland types in El-Haouch region

3.4 Relationship between vegetation and soil properties

Figure 06 (A) shows that the axe F1 (40.40%) and **F2 (27.40%)** are the first two principal components, **CE**, ***Retama raetam***, and ***Thymelaea microphylla*,** suggesting a **positive correlation** among them. ***Atriplex halimus*** and ***Tamarix gallica*** are **negatively correlated** with CE, and *Retama retam*, Wadi rangeland (WR) are associated with ***Atriplex halimus*** and ***Tamarix gallica***, (SR) are associated with ***Retama retam*** and ***Thymelaea microphylla***. **CaCO3** positive correlated with *Suaeda* ***vermiculata*** in salty accumulation formation (SalR). **Principal Component Analysis biplot (fig. 06 B)**, showing the relationships between **species**, **edaphic parameters**, and **sample** sites along two principal axes (F1 and F2), which together explain **72.64%** of the total variation in the data (F1 = 52.25%, F2 = 20.39%). ***Tamarix gallica*** and ***Salsola vermiculata*** are associated with low pH, low $CaCO_3$, and low CE. ***Thymelaea microphylla*** (SR) correlated with high $CaCO_3$ and CE.

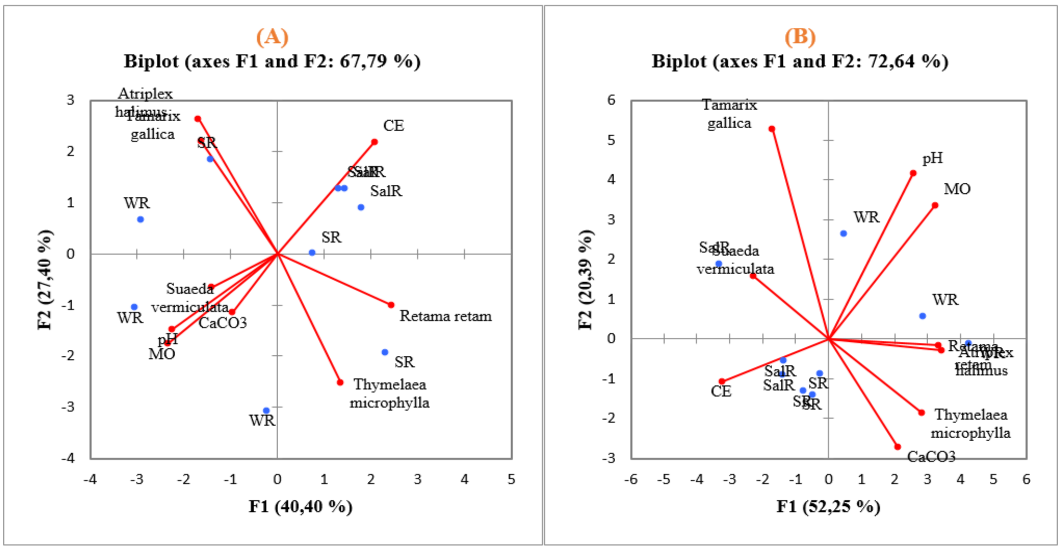

Figure 06: CPA-ordination diagrams of physico-chemical character of soil and vegetation (A) in 2017/2018, and (B) 2018/2019

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

3.5 Implications of climate change on soil properties

Climate change significantly impacts soil properties in arid rangeland by altering their physical, chemical, and biological characteristics. The alterations in temperature and precipitation patterns lead to changes in soil organic matter, nutrient availability, and microbial activity. These shifts can impact forage quantity and quality, livestock metabolism, and plant community composition.

3.5.1. Patterns and trends in temperature

According to the Mann-Kendall trend test, the annual mean temperature series (1987-2019) showed a significant upward trend ($\tau b = 0.293$, $p < 0.05$) from 1987 to 2019. However, in 2017/2018, the trend was not significant ($\tau b = 0.121$, $p > 0.05$). $\tau b = 0.212$, $p>0.05$ (2018/ 2019).

Likewise, the maximum temperature exhibited a significant increasing trend for the series from 1987 to 2019 ($\tau b = 0.399$, $p < 0.05$). Besides, the series of minimum temperatures showed no significant change in the minimum observed, respectively, for (1987-2019) with $\tau b = 0.018$, $p>0.05$, (2017-2018) with $\tau b = 0.242$, $p>0.05$, and (2018-2019) with $\tau b = 0.242$, $p>0.05$.

The null hypothesis of homogeneity of the maximum temperature data from 1987 to 2019 was rejected, according to the test of Pettitt's (K = 206.000, p< 0.05). Figures 07, 08, and 09indicate this increasing temperature trend, mainly the mean temperature (1987-2019), and the maximum temperature from 1987 to 2019.

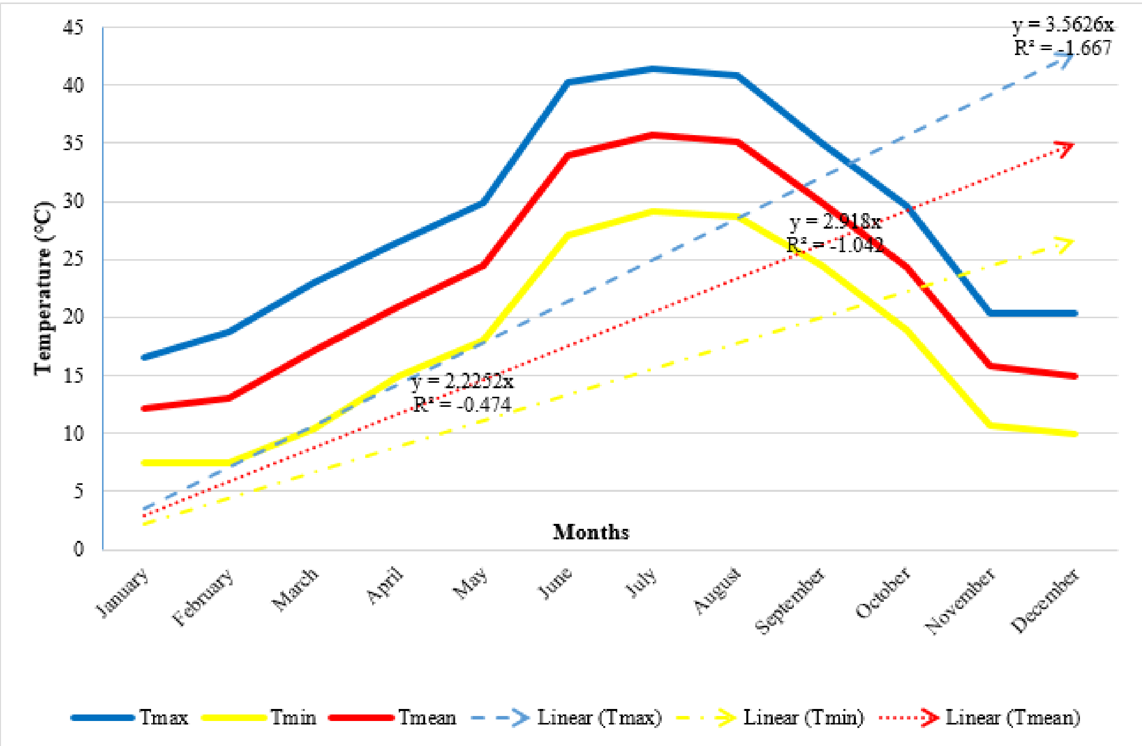

Figure 07: Trend of the mean, minimum, and maximum monthly temperature in El-Haouch region in 2018

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

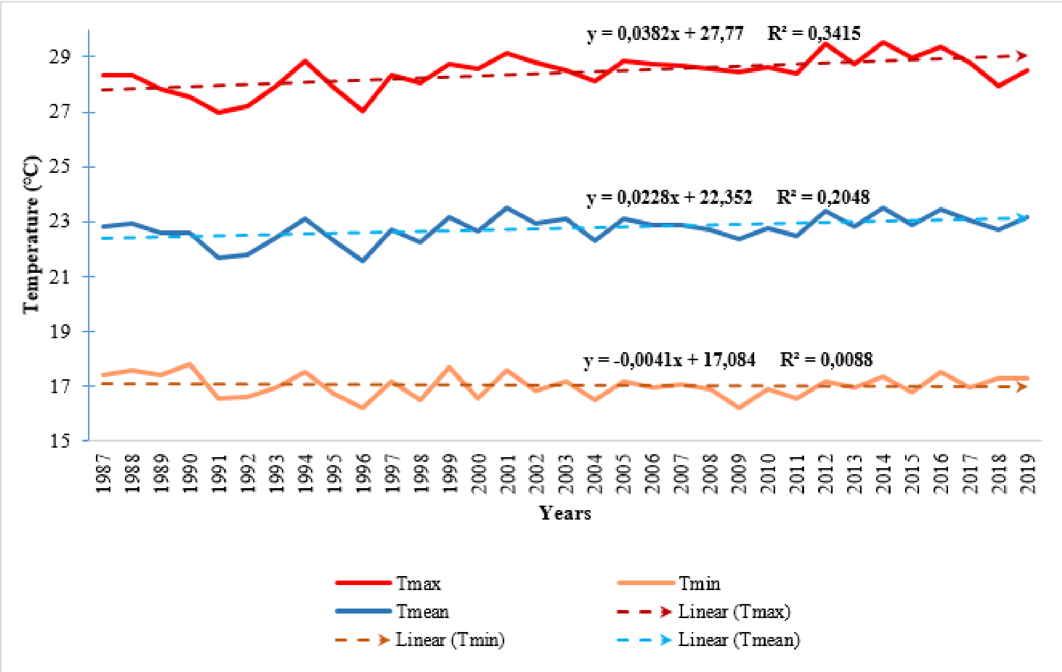

Figure 08: Trend of the mean, minimum, and maximum monthly temperature in El-Haouch region in 2019

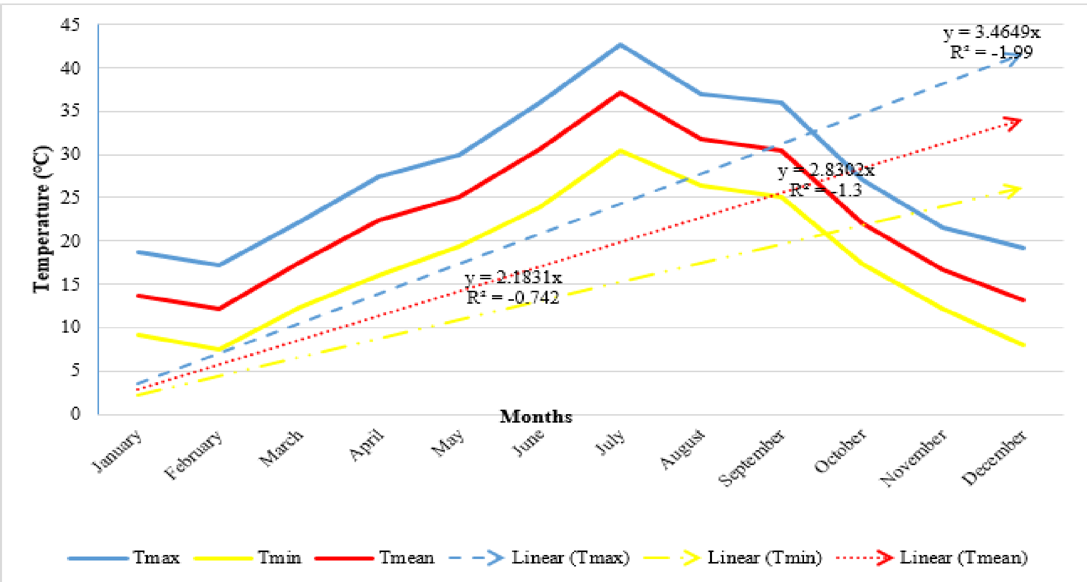

Figure 09: Trend of the mean, minimum, and maximum annual temperature in El-Haouch region from 1987 to 2019

3.5.2. Patterns and trends in precipitation

Figure 10 shows **monthly variation across three time periods (1987/2019, 2017/2018, and 2018/2019)**, along with **trend lines** (linear regressions) for each dataset. Precipitation in the study area is characterized by medium variability, with variation coefficients of 0.49 % in (1987-2019), 1.51 % (2017/2018), and 1.21 % (2018/2019). Indeed, the average annual rainfall was 152 mm for the period between 1987 to 2019, 115 mm (2017/2018), and 96 mm

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

(2018/2019). The rainfall series is considered to indicate a general downward trend in the annual amounts of precipitation. To determine if there is a significant trend within the rainfall series studies, a Mann-Kendall test was conducted. The results obtained by the Mann-Kendall trend test ($\tau b = 0.062$, $p > 0.05$) in (2017/2018), and ($\tau b = 0.030$, $p > 0.05$). Overall, a general regression trend of the annual rainfall amounts is observed between the recording periods (Figure 10).

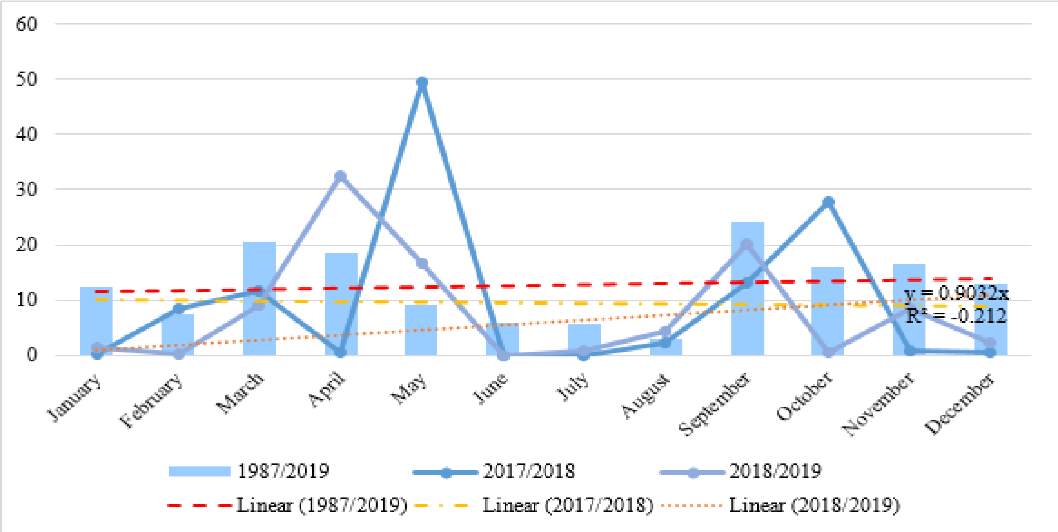

Figure 10: Trend oaf annual rainfall series (1987- 2019), (2017-2018), and (2018-2019) in Biskra station

3.6. Discussion

The study investigated the physicochemical properties of soils in the arid rangelands of El-Haouch, Biskra (Algeria), focusing on parameters such as electrical conductivity (EC), calcium carbonate ($CaCO_3$), pH, organic matter (OM), and soil texture. It also examined the implications of these soil characteristics, along with climate change, on the spatial distribution of plant cover in the arid steppe rangeland ecosystem. The electrical conductivity (EC) in arid rangelands is a critical indicator of soil salinity (Bouaroudj et al., 2019; Guemmaz et al,. 2019). Our findings reveal that zones with salt accumulation in depressions exhibit the highest electrical conductivity (EC) values, indicating substantial salinization of these areas (Mathieu & Pieltain, 2003; Neffar et al., 2016). Likewise, Tavili et al., (2009) suggested that EC is positively correlated with plant cover, highlighting its significance in the distribution of vegetation in southern Khorasan rangelands. This phenomenon is closely linked to the domination of *Atriplex halimus*, a halophytic species capable of absorbing and storing significant amounts of sodium in its foliage. Besides the improvement of water percolation by roots reduces salt content, other factors can be responsible for low EC in the Wadi beds (WR).

High bushy vegetation cover of the soil surface can mitigate evaporation and decrease soil salinity in dry environments (Zhang et al., 2004). Following leaf abscission, the decomposition of these sodium-enriched leaves releases salts into the soil, leading to increased alkalinity. This process has been similarly observed in other studies (Al-Muwayhi, 2020; Guo et al., 2020). Supporting this, Rabhi et al., (2009) also documented the alkalizing effect of halophytic vegetation on soil properties. The salinization in depressions is driven by factors such as; high evaporation rates in arid regions lead to salt accumulation as water evaporates, leaving salts behind in the soil (El-Horiny, 2019; Pedrotti et al., 2015), and the geological

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

composition of the landscape can predispose areas to salinization, particularly in endorheic zones where water does not drain away (Laoufi et al., 2023); fluctuating shallow groundwater levels lead to increased soil salinity, the higher fluctuation rates result in greater salt accumulation in the soil profile(Ibrahimi et al., 2014); the use of highly mineralized irrigation water is a significant contributor to soil salinization. (Djili et al., 2003). The depression has the highest EC; consequently, the geological formations on the Bahariya Oasis in the Western Desert of Egypt, ranging from lower Miocene to Quaternary deposits, contribute to the salinity levels, as evaporation exceeds precipitation, leading to increased salt concentration in the soil (El-Horiny, 2019).

The sandy soil in site 2 (SR), had high CaCO3 concentrations, various environmental factors and soil characteristics, such as vegetation cover, climatic conditions, and parental material can significantly influence CaCO3 distribution in arid rangelands (Sharafatmandrad, 2019). Sanjerehei, (2012) shows that soil texture significantly influences vegetation distribution in arid rangelands, as indicated by the study. It, along with lime, salinity, and organic matter, influences the presence of species such as *Salsola tomentosa* and *Peganum harmala* in the Nodushan rangelands. Similarly, Su et al., (2015) found that the soil texture significantly influences vegetation distribution in arid rangelands, with clay and silt content positively correlating with biomass in these ecosystems. Sandy loam texture in arid rangelands plays a crucial role in soil water retention, vegetation productivity, and overall ecosystem health. This texture supports diverse plant communities, enhancing ecosystem resilience against drought (Su et al., 2015). Loam textures enhance water retention, indicating that matric potential is influenced by soil type and precipitation patterns on arid rangeland of southern Mexico (Herbel & Gibbens, 1989).

High levels of $CaCO_3$ in the study area, especially in Aeolian formation (*Retama retam* and *Thymelaea microphylla*), justify the profusion of $CaCO_3$, which in turn determines soil pH and EC (Gulzar et al., 2014). According to Boudjabi et al., (2022), $CaCO_3$ contributes to soil alkalinity, with multiple studies showing that higher $CaCO_3$ concentrations correlate with increased pH levels in semi-arid steppe rangelands of Algeria. The presence of $CaCO_3$ affects the ionic composition of the soil solution, which is crucial for EC measurements. Increased $CaCO_3$ can enhance the mobility of cations like Ca^{2+}, thereby influencing EC levels (Peker et al., 2024). Soil salinity was nevertheless identified as a critical factor influencing the distribution of halophytic species within the study area. The calcium carbonate ($CaCO_3$) stabilizes aggregates in calcareous arid soils, influencing organic carbon distribution. This stabilization may affect vegetation dynamics, as changes in soil carbon can impact the resilience and distribution of dominant plant species in semiarid ecosystems (Cunliffe et al., 2016). The soil pH was higher in the three sites. Despite the sites having an alkaline pH (Baize, 2018). This parameter, considered among the most important soil indicators (Li et al., 2006), is strongly influenced by the parent material (Baskan et al., 2016). pH significantly influences vegetation distribution in arid rangelands by affecting nutrient availability and soil properties, resulting in distinct patterns of plant community dynamics. *Atriplex halimus* and *Tamarix gallica* occurred in areas with high soil pH, whereas *Retama retam* and *Thymelaea microphylla* characteristically colonized sites of moderately saline environments. Our results align with those of Di Bella et al., (2014), who reported that species composition in salt marshes can be predicted based on soil characteristics, primarily soil salinity, which varies with elevation. In addition, pH affects the solubility and availability of essential nutrients. For instance, higher pH can increase soil availability of sulfate but decrease plant uptake, complicating nutrient dynamics (Barrow & Hartemink, 2023).

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

Organic matter (OM) significantly influences vegetation distribution in arid rangelands through various mechanisms, primarily involving water and nutrient dynamics. The interplay between OM and environmental factors shapes vegetation patterns, which are crucial for ecosystem resilience in these challenging climates. The classification of soils according to the percentage of organic matter shows that soils in the study area are low in organic matter, which is consistent with findings by Nadjraoui & Bedrani, (2008), who reported that soil OM content is largely influenced by climatic aridity and vegetation cover. Similarly, Pouget, (1980) and Djebaili, (1984) estimated an average of organic matter content of 1–2% in steppe soils.

While Wadi rangelands have the highest pH and organic matter, in this context, the study conducted by Zandi et al., (2017), shows beneficial soil properties like pH and OM in semi-arid rangeland compared to agricultural lands; it is essential to consider the impact of land use changes, as agricultural practices can lead to declines in soil quality and organic matter content in arid and semi-arid ecosystems. Physiologically, plants respond to salinity in a species-dependent manner (Mercado et al., 2014; Gul et al., 2016). *Atriplex halimus* and *Tamarix gallica* in Wadi beds were closely associated with pH, OM in RDA analysis, and seem to be adapted to most saline soils. Indeed, *Chenopodiaceae* species are often associated with high saline environmental conditions (Naz et al., 2013; Rozema & Schat, 2013). In ephemeral salt wetlands of hot arid and semiarid areas, particularly in North Africa and the Middle East, *Atriplex halimus* and *Suaeda vermiculata* are considered as fugitive species of wet hypersaline habitats, because of their ability to support a high degree of salinity through osmoregulation processes (Engels et al., 2011; Rozema & Schat, 2013; Flowers & Colmer, 2015). However, *Atriplex halimus* is found to occupy areas with moderate and low salinity, whereas *Tamarix gallica* occurs in wet and low-salinity soils. Percolation of water, elimination of salts, and enrichment of soil with organic matter are favored when the network of roots (or rhizomes) is dense in certain species, such as *Juncus*, which reduces salt stress for other species (Boscaiu et al., 2013).

Climate change significantly influences vegetation distribution in arid rangelands through mechanisms such as altered precipitation patterns, increased temperatures, and aridity. These changes can lead to shifts in plant community composition, reduced forage quality, and increased vulnerability to degradation. Our findings show a decreasing trend in rainfall and an increase in temperature over 33 years (1987-2019) in the study area. Belhadj et al., (2023 b); Gbetibouo, (2009); Ouédraogo et al., (2010) ; Vissoh et al., (2012); Tamiru et al., (2014); Opiyo et al., (2015); Ndamani & Watanabe, (2016) confirm the same phenomenon over the last decades in many African countries. Climate change influences vegetation distribution in arid rangelands by altering temperature and precipitation patterns, affecting soil nitrogen availability and plant growth. Increased heat and drought stress can favor generalist species, leading to vegetation homogenization and reduced ecosystem function (Polley et al., 2017). Drier conditions exacerbate grazing impacts, promoting shrub encroachment and reducing palatable grasses, thus affecting overall vegetation dynamics and recovery potential. (Cipriotti et al., 2019).

4. CONCLUSIONS

This work highlighted the importance of studying the influence of soil parameters and climate change on the distribution of vegetation in the arid rangeland of El Houche (Algeria). Our results confirmed that soil parameters were a significant factor, as well as soil salinity, which was critical in shaping the distribution of halophyte species. Soil salinity (along with

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

pH, OM, and $CaCO_3$ concentrations) and the distribution of plant species reflect these changes in arid rangeland type. For example, *Atriplex halimus* and *Suaeda vermiculata* occupied salty accumulations with high salinity and low OM. In contrast, *Retama retam* and *Thymelaea microphylla* occupied aeolian formations with high concentrations of $CaCO_3$, medium soil salinity, and low OM. The statistical analysis of climate data revealed a noticeable trend of decreasing precipitation and an increase in temperature. Arid rangelands are very fragile, unstable, and threatened by various degradation factors, including environmental, socioeconomic (overgrazing, agricultural expansion), and climatic factors. It is highly recommended to update the status of species in terms of restoration and conservation.

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Volume 64 | Issue 11 | November 2025
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Volume 64 | Issue 11 | November 2025
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Volume 64 | Issue 11 | November 2025
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Appendix

Systematic list of families, genre, lifecycle forms and plant species identified in arid steppe of southeast Algeria (Biskra) (WR)Wadi beds, (SR) sandy soils, (SalR) saline accumulation (P: Perennial, A: Annual, +: Presence, -: Absence)

Volume 64 | Issue 11 | November 2025
DOI: 10.5281/zenodo.17710340

				2017			2018		
Family	**Genre**	**Species**	**Lifecycle forms**	**WR**	**SR**	**SalR**	**WR**	**SR**	**SalR**
Amaranthaceae	**Arthrocnemum**	*Arthrocnemum glaucum* (Moric.) K. Koch	P	-	-	+	-	-	+
Asteraceae	**Artemisia**	*Artemisia campestris* L.	P	+	-	-	+	-	-
	Atractylis	*Atractylis aristata* Batt.	P	+	-	-	+	-	-
	Centaurea	*Centaura pungens* Pomel.	A	-	-	-	+	-	-
	Echinops	*Echinops spinosus* L.	A	-	+	-	-	+	-
	Rhanterium	*Rhantherium suaveolens* Desf.	P	+	-	-	+	-	-
Boraginaceae	**Echium**	*Echium vulgare* L.	A	-	-	-	+	-	-
Chenopodiaceae	**Anabasis**	*Anabasis articulata* Forssk.	P	+	+	+	+	++	+
	Atriplex	*Atriplex halimus* L.	P	+++	-	+	+++	+	++
	Salsola	*Salsola tetrandra* Forssk.	P	-	-	+	-	-	+
	Spinacia	*Spinacia oleracea* L.	A	+	-	-	+	-	-
	Suaeda	*Suaeda vermiculata* Forssk.	P	-	-	++	-	-	+
	Traganum	*Traganum nudatum* Delile.	P	-	-	-	-	-	+
Euphorbiaceae	**Euphorbia**	*Euphorbia cornuta* Forssk.	A	+	-	-	-	-	-
Fabaceae	**Astragalus**	*Astragalus armatus* Willd.	P	+	+	-	+	+	+
	Cassia	*Cassia italica* Mill.	P	-	-	-	+	-	-
	Retama	*Retama retam* (Forssk.) Webb	P	-	++	-	-	+	+
Globulariaceae	**Globularia**	*Globularia alypum* L.	A	+	-	-	+	-	-
Lamiaceae	**Ballota**	*Ballota hirsuta* (Willd).	A	+	-	-	-	-	-
Malvaceae	**Malva**	*Malva aegyptiaca L.*	A	+	-	-	+	-	-
Poaceae	**Aristida**	*Aristida pungens* Desf.	P	-	+	-	-	+	-
	Cynodon	*Cynodon dactylon* L.Pers.	A	+	-	-	+	-	-
	Lolium	*Lolium multiflorum* Lam.	A	+	-	-	+	-	-
Rhamnaceae	**Ziziphus**	*Zizyphys lotus* (L). Lam.	P	-	-	-	+	-	-
Tamaricaceae	**Tamarix**	*Tamarix gallica L.*	P	++	-	+	+++	+	+
Thymeliaceae	**Thymelaea**	*Thymelaea microphylla* Coss. & Durieu ex Meisn.	P	-	++	-	-	++	-
Zygophyllaceae	**Peganum**	*Peganum harmala* L.	P	+	-	+	+	-	-