EFFECTS OF SOIL CHARACTERISTICS ON DISTRIBUTION OF VEGETATION TYPES IN POSHTKOUH RANGELANDS OF YAZD PROVINCE (IRAN)

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ABSTRACT

The objective of this research was to study the relationships between soil characteristics and vegetation in order to find the most effective factors in the separation of the vegetation types in Poshtkou rangelands of Yazd province. After delimitation of the study area, sampling of soil and vegetation were performed with randomized-systematic method. Vegetation data including density and cover percentage were estimated quantitatively in each plot, and with the help of two-way indicator species analysis (TWINSPAN), vegetation was classified into different groups. The topographical conditions were recorded in plot locations. Soil samples were taken at depths of 0-30 and 30-60 cm in each plot. The measured soil variables included texture, lime, saturation moisture, gypsum, acidity (pH), ECe, SAR, and soluble ions (Na^+, K^+, Mg^{2+}, Cl^-, Co_3^{2-}, HCo_3^- and So_4^{2-}). Multivariate methods including principal component analysis (PCA) and canonical correspondence analysis (CCA) were used to analyze the collected data. The results showed that the vegetation distribution pattern was mainly related to soil characteristics such as salinity, texture, soluble potassium, gypsum and lime. Totally, each plant species due to the habitat conditions, ecological needs and tolerance has a significant relation with soil properties.

Key Words: Poushtkouh Rangelands, Vegetation type, Soil characteristics, Principal component analysis, Canonical correspondence analysis, Ordination.

INTRODUCTION

The analysis of species–environment relationship has always been a central issue in ecology.[1] For over a century, ecologists have attempted to determine the factors that control plant species distribution and variation in vegetation composition. Arid and semi-arid regions are characterized by minimal precipitation and frequent droughts; thus water availability is one of the primary factors controlling the distribution of species. Abiotic factors related to water availability include annual precipitation (AP), soil properties, and topography. Rooting depth, soil water potential, absorption, and distribution of nutrients are influenced by the amount and availability of soil moisture.[1,3]

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Among deferent environmental, soil is a function of climate, organisms, topography, parent material, and time. Soil characteristics play major role in distribution of plant species. Leonard et al found that vegetation cover has the most relationship with temperature and soil moisture. Other soil characteristics, directly or indirectly influence on two mentioned parameters. Rooting depth, potential of soil water, absorption and distribution of nutrient are influenced by amount and period of available moisture in soil. In this relation, soil temperature in the approximately rhizosphere is very important. Soil moisture gradient influenced by the soil characteristics such as; texture, argil type, horizons borderline, structure, solution salts, gravely, depth, and soil temperature. Also, soil moisture changes in term of topography (elevation, aspect, slope) and the other factors such as microtopography, amount of litter on soil surface etc.

Ayyad determined that edaphic factors provided the primary explanation for describing the distribution of plant communities in the Western Desert of Egypt.[4,5]

Zare investigated rangelands in Kavir-e-Phino of Hormozgan province and showed that some factors such as slope, aspect, saturation moisture percentage and soil depth had the most effective role on yield of plant species. Makarenkov and Legendre investigated the effects of water content and reflection of soil radiation on vegetation cover percentage of *Calmagrostis epigejos* and *Corynephrous canescens* using multivariate analysis such as CCA, RDA and non-linear regression. They found that *C. epigejos* is the indicator of wet sites while *C. canescens* indicates dry sites. Iravani et al studied the environmental factors (edaphic, climate, and topographic factors) in habitat of range species namely *Festuca ovina*, *Cachrys ferulacea*, and *Bromus tomentellus* in Vahargan river chatchment using ordination methods (PCA, CCA). He showed that the edaphic factors are the most important environmental factors in separation of three habitats.[4-6]

As mentioned above, the main purpose of this research was to investigate the relationships between soil characteristics with plant species to determine the most important factors affecting the separation vegetation types. By knowing the relationships between soil and vegetation, it is possible to apply these results for similar region and recommend the suitable guidance for management, reclamation and development of rangelands. The other aims were to identify limiting factors in establishment of vegetation in order to determine the suitable methods for land reclamation, and also introduce adaptable species according to the soil characteristics in the study area.

MATERIAL AND METHODS

The study area was Poshtkouh rangelands, located in southern slopes of Shirkouh mountainous region of Yazd province of Iran (31º 2´ N, 53º 45´ E to 31º 34´ 31´´ N, 54º 33´ E). The maximum elevation of the region is 3970 m and the minimum elevation is 1450 m in margin of Kavir-e-Abarkouh. Average annual precipitation of the study area ranges from 250mm in Shirkouh mountain to 80 mm in margin of Kavir-e-Abarkouh.

Data collection

With attention to research aims and due to survey of vegetation and environmental factors, study area was delimited in Poshtkouh rangelands of Yazd province. According to vegetation map and field surveys, vegetation types were determined. In each vegetation type, sampling was done in key area. Key area is representative of total characteristics of each type. The area of each plot was determined according to the kind of plant species and distribution of plants. Considering the extent of vegetation type, variation in vegetation and environmental factors, in each vegetation type sampling was done in 10 plots and the distance of plots was determined 50 m. Method of sampling was randomized-systematic.

List of plant species, density and canopy cover percentage were determined in each plot. Then, considering borderline average of each soil horizon, soil samples were taken from 0-30 and 30-60 cm layers. The measured soil variables included texture, lime, saturation moisture, gypsum, acidity (pH), ECe, SAR, and soluble ions (Na^+, K^+, Mg^{2+}, Cl^-, Co_3^{2-}, HCo_3^- and SO_4^{2}).

Data analysis methods

The PC_ORD (McCune & Meford, 1997) was used for classification and ordination of vegetation types in gradient of soil characteristics. Data were analyzed by a series of multivariate techniques such as the two way indicator species analysis (TWINSPAN), principal component analysis (PCA) and canonical correspondence analysis (CCA).[5-7]

To use TWINSPAN analysis, the cover data transformed using an eight-point scale ((01=0.5, 1–2.5=1.75, 2.5–5=3.75, 5–7.5=6.25, 7.5–12.5=10, 12.5–17.5=15, 17.5 22.5=20, 22.5–27.5=25, >27.5=30) (Scale Van-der-Marrel, 1979)). TWINSPAN analysis is a numerical method for classification of vegetation belonging to similar groups. This allows the investigator to recognize the homogenous groups. After classification of the vegetation, relationships between soil and vegetation were studied using PCA and CCA.

To apply PCA, data standardization is necessary if we are analysing variables that are measured in different units. Also, species with high variance, often the abundant ones, therefore dominate the PCA solution, whereas species with low variance, often the rare ones, have only minor influence on the solution. These maybe reasons for applying the standardized PCA, in which all species receive equal weight. Therefore, data was centered and standardized by standard deviation. Eigenvalues for each principal component was compared to a broken-stick eigenvalue to determine if the captured variance summarized more information than expected by chance. Broken-stick eigenvalues have been shown to be a robust method for selection of non-trivial components in PCA. Principal components are considered useful, or non-trivial, if their eigenvalue exceeds that of their broken-stick counterpart.

CCA is the new technique that selects the linear combination of environmental variables that maximizes the description of the species scores. On the other hand, CCA chooses the best weights for the environmental variables. This gives the first CCA axis. In CCA, composite gradients are linear combinations of environmental variables, giving a much simpler analysis, and the non-linearity enters the model through a unimodal model for a few composite gradients, taken care of in CCA by weighted averaging. Canonical ordination is easier to apply and requires less data than regression. It provides a summary of the species–environment relations.[7] Significance of the species–environment correlation was tested by the distribution-free Monte Carlo test (1000 permutations). In the Monte Carlo test, the distribution of the test statistics under the null hypothesis is generated by random permutations of cases in the environmental data.

RESULTS AND DISCUSSION

TWINSPAN

TWINSPAN was performed for vegetation analysis in 90 plots using ordinal scale of Van-der-Marrel (1979). The results of TWINSPAN classification are presented in **Fig. 1**. According to the above-mentioned figure, and also eigenvalue of each division, vegetation of the study area was classified into seven main types. Each type differs from the other in terms of its environmental needs. These types are as follows:

1. *Ephedra strobilacea,*
2. *Cornulaca monocantha,*
3. *Artemisia aucheri–Astragalus sp.,*

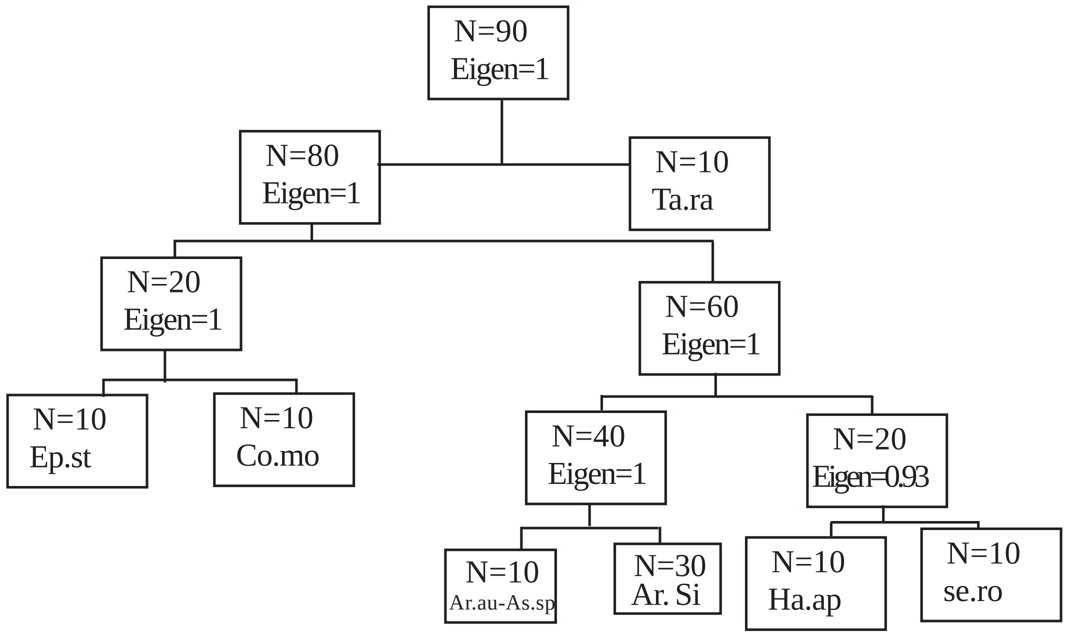

Fig. 1. Dendrogram of TWINSPAN for vegetation in the studyarea. For species abbreviations, see

4. *Artemisia sieberi*,
5. *Haloxylon aphyllum*,
6. *Seidlitzia rosmarinus*, and
7. *Tamarix ramosissima*.

In addition, *A. sieberi* type includes subtypes such as *A.sieberi–Dorema ammoniacum*,

A. sieberi–Salsola rigida. According to the results of vegetation classification, quadrates were classified into different groups. PCA and CCA were used to determine the most effective environmental factors in the separation of vegetation types and to find the relationships between the existing plants and environmental factors.

PCA

The results of the PCA ordination are presented in **Table 1** and **Fig. 2**. Broken-stick eigenvalues for data set indicate that the first two principal components (PC1 and PC2) resolutely captured more variance than expected by chance. The first two principal components together accounted for 86.03% of the total variance in data set. Therefore, 72.34% and 13.69% variance were accounted for by the first and second principal components, respectively. This means that the first principal component is by far the most important for representing the variation of the seven vegetation types. Considering the correlations between variables and components, the first principal component includes environmental factors such as calcium, magnesium, bicarbonate and gypsum in the first layer (0–30 cm), clay and sand in the second layer (30–60 cm), and saturation moisture, ECe, sodium absorption ratio (SAR), soluble ions (Na^+, Cl^-, CO_3^{2-}, SO_4^{2-}) in both layers. Axis 1 seems to represent essentially soil salinity, texture, gypsum and potassium gradient, while axis 2 is reflecting a gradient of elevation, slope, pH and lime in the first layer and silt in the second layer. As mentioned above, PC1 accounted for 72.34% of the total variance, which is related to soil properties. Therefore, among all environmental factors, soil characteristics such as salinity, texture, gypsum and potassium are the most effective factors in the distribution of vegetation types.

Fig. 2 shows a plot of the seven vegetation types against their values for axes 1 and 2. For *H. aphyllum*, *S. rosmarinus*, and *C. monocantha* types comforted in the first quarter of the co-ordinate axes. These types have inverse relation with PC1 factors, except for sand in the second layer, and PC2 factors, except for lime and acidity. Relation power depends on the length of vector loading and the angles between vectors and axes. In addition, in *H. aphylum* and *S. rosmarinus* types environmental characteristics are approximately similar in axes 1 and 2.

In the study area, environmental conditions in *T. ramosissima* type differ from the others. With attention to the position of this type in the third quarter of the diagram, it has a high correlation with the first axis. Therefore, this type has the most relation with variables of the first axis (ECe, gypsum, potassium and clay). Because of the bigger distance of *T. ramosissima* type from the second axis, this type has a weak relation with factors such as elevation, slope, acidity and lime. *E. strobilacea*, *A. sieberi* and *A. aucheri–As. sp*. types have inverse relation with indicator environmental characteristics of the first and second axes except for elevation, slope, sand and silt in the second layer. *A. aucheri–As. sp*. type has more relation with indicator characteristics of the first and second axes. Indicator environmental factors of the first and second axes in *E. strobilacea* and *A. sieberi* types are approximately similar. *A. aucheri–As. sp*. type has a direct relationship with elevation and slope, and an inverse relationship with lime and pH, while *S. rosmarinus* and *H. aphyllum* types have a direct relationship with lime and pH, and are inversely related to elevation and slope. Also, in terms of ECe and soluble ions rate *A. aucheri–As. sp*. type shows a different behavior in comparison to *T. ramosissima* type.

Table 1 : PCA applied to the correlation matrix of the environment factors in the study area

Axis	Eigenvalue	% of Variance	Cum. % of Var.	Broken-stick Eigenvalue
1	27.49	72.341	72.341	4.228
2	5.202	13.69	86.031	3.228
3	2.466	4.488	92.519	2.728
4	1.346	3.542	96.061	2.395
5	1.172	3.085	99.146	2.145
6	0.324	0.854	100	1.945
7	0	0	100	1.778
8	0	0	100	1.635
9	0	0	100	1.51
10	0	0	100	1.399

Factor	PC1*	PC2*	PC3	PC4	PC5	PC6
$Gravel_1$	0.1365	-0.2348	0.1008	0.3518	0.0069	0.168
$Gravel_2$	0.1615	-0.0742	0.2134	0.1582	-0.1056	0.5426
$Clay_1$	-0.1849	-0.0265	0.0238	0.0173	0.1531	0.2873
$Clay_2$	-0.1824	-0.0652	0.1274	-0.0138	0.1406	0.0224
$Silt_1$	-0.165	-0.1795	-0.0183	-0.1528	0.1971	0.1429
$Silt_2$	-0.1723	-0.1842	-0.0219	0.0212	0.0514	-0.0887
$Sand_1$	0.1817	0.0838	-0.009	0.0455	-0.172	-0.2404
$Sand_2$	0.1819	0.1073	-0.0843	-0.002	-0.104	0.0096
Sm_1	-0.1888	-0.0558	-0.007	0.0087	-0.0302	-0.0903
Sm_2	-0.1886	-0.0294	-0.02	-0.0038	0.0805	-0.1653
$Gypsum_1$	-0.1888	-0.0342	-0.0658	0.0015	-0.0127	0.0997
$Gypsum_2$	-0.0071	-0.0273	-0.5446	-0.3771	-0.1884	0.3068
$Lime_1$	0.0111	0.3812	-0.1042	0.2844	0.287	0.1701
$Lime_2$	0.002	0.3687	0.0246	0.2878	0.3915	0.0048
pH_1	-0.095	0.3585	0.1113	0.0393	-0.0934	0.3534
pH_2	-0.0908	0.3099	0.223	-0.1415	-0.3201	0.1138
EC_1	-0.1896	-0.0345	0.0292	0.0471	-0.0105	-0.01257
EC_2	-0.19	-0.0043	0.0017	0.0687	-0.0058	0.0606
Na_1	-0.1893	-0.0409	0.0354	0.0412	-0.0137	-0.0313
Na_2	-0.1896	-0.0307	0.0372	0.0521	-0.0137	-0.0024
K_1	0.0311	-0.0496	0.317	-0.5337	0.5258	0.1274
K_2	-0.1849	0.0216	0.0928	0.0777	-0.1454	0.1095
Ca_1	-0.1887	-0.0237	-0.0852	-0.0049	-0.0161	0.0125
Ca_2	-0.1228	0.071	-0.4635	-0.0431	0.0369	0.2803
Mg_1	-0.1899	-0.0036	-0.0146	0.07	0.0106	-0.0742
Mg_2	-0.1612	0.0878	-3023	0.0821	0.0427	-0.1664
Cl_1	-0.1894	-0.0402	0.0342	0.0408	-0.015	-0.0355
Cl_2	-0.1897	-0.0268	0.0313	0.0562	-0.01	-0.0039
Co_1	-0.1892	-0.044	0.0375	0.0353	-0.0192	-0.0413
Co_2	-1888	-0.0305	0.0586	0.0337	-0.065	-0.0231
Hc_1	-0.1892	-0.009	0.0963	0.0222	-0.0525	0.0272
Hc_2	-0.1174	0.1608	0.3153	-0.2368	-0.3759	0.0198
So_1	-0.1897	-0.0345	0.0256	0.0484	-0.0067	-0.0085
So_2	-0.1902	-0.0143	-0.0188	0.0512	-0.0063	0.0143
SAR_1	-0.1896	-0.0297	0.0364	0.0553	-0.0122	-0.0009
SAr_2	-0.189	-0.0121	0.0604	0.0545	-0.0553	0.0249

For abbreviation and units, see Appendix A.
*Non-trivial principal component as based on broken-stick eigenvalues.

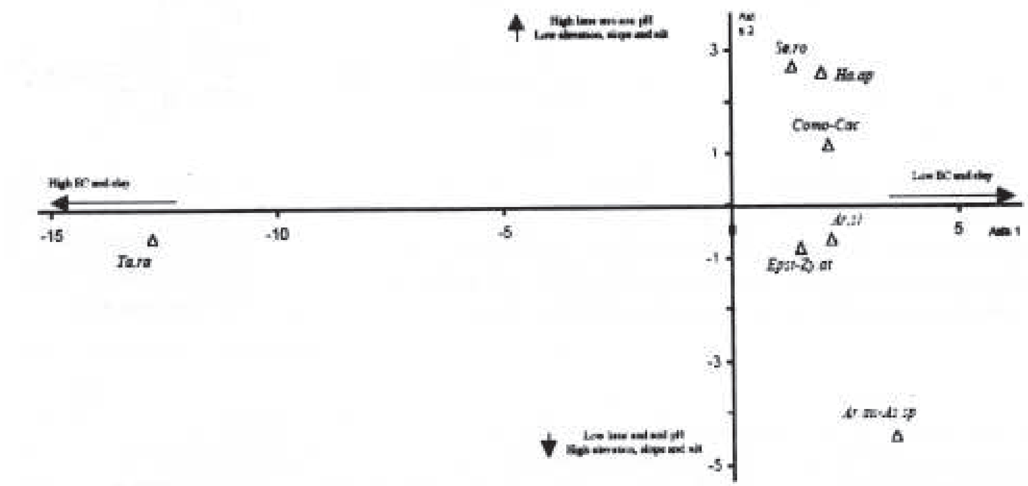

Fig. 2 : PCA–ordination diagram of the vegetation types related to the environmental factors in the study area. For vegetation types abbreviations, see Appendix A.

CCA

The results of CCA ordination are presented in **Fig. 3**. Three groups were determined in relation to the environmental factors. Each environmental factor is an indicator of the specific habitat. *A. sieberi* type has non-linear relation with soluble potassium in the first layer, that is, soluble potassium is the indicator of habitat of this type. *A. aucheri*–A. sp., *E. strobilacea*, *S. rosmarinus* and *C. monocantha* types have nonlinear relation with slope, elevation, gypsum, gravel, sand, lime, acidity, calcium and soluble magnesium. Relation power depends on the relative distance between indicator points of soil characteristics and vegetation types. The above-mentioned types represent soils with light texture. *A. aucheri–As. sp*. type occurs in the soils with light texture and low soluble content, while the other mentioned types are associated with moderate-to-high soluble content soils. Soils with heavy texture, high salinity and soluble ions rate (particularly sodium and chlorine) indicate *T. ramosissima* habitat.

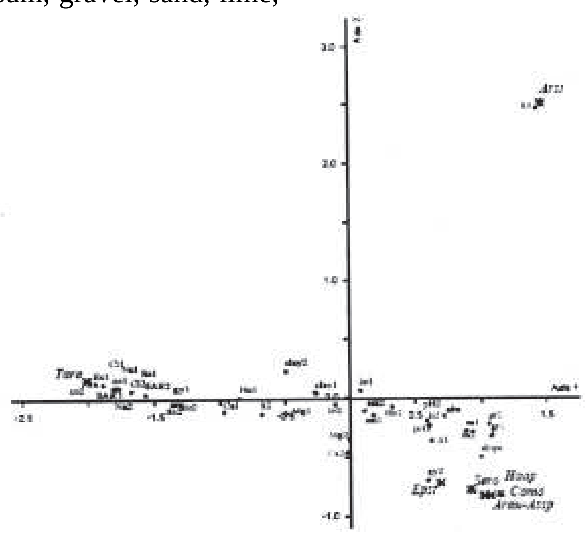

Fig. 3 : CCA–ordination diagram of the environmental data. For vegetation types and variables abbreviations, see Appendix A. (*) is the representative of the vegetation types. (ô) is the representative of the environmental factors.

CONCLUSION

The results showed that in the study area, among different environmental factors (topographic and edaphic variables), the distribution of vegetation types was most strongly correlated with some soil characteristics such as salinity, texture, potassium, lime and gypsum. In arid and semi-arid regions, the relation between species distribution and salinity gradient has been reported by many investigators[2-7] also showed strong relationships between vegetation pattern and soil moisture–salinity gradient in the Kharga and Dakhla Oases. Soil texture controls distribution of plant species by affecting moisture availability, ventilation and distribution of plant roots. The role of soil moisture, as a key element in the distribution of the plant species, is described by Zohary and Orshan in the Dead Sea region of Israel and El-Sheikh and Yousef in Al-Kharg springs. Also, in the study area, potassium is one of the effective factors in the distribution of vegetation types. Jensen et al suggested that K/Mg ratio is an indicator of grasslands and shrublands separation. High K/Mg ratio is suitable for shrub growth. In the present study, combination of PCA and CCA results showed that potassium indicates *A. sieberi* type. *T. ramosissima* has strong relationship with soil salinity and heavy texture. This species showed a trend to high soluble rate, salinity and Clay percent age. A. aucheri–As. sp., *H. aphyllum*, *E. strobilacea*, *C. monocantha* and *S. rosmarinus* types indicate hillslope lands and also soils with light texture and changeable solubles, and hence *A. aucheri–As. sp.* site is located in the soils with low soluble content, while the others are in the soils with average-to-high soluble content. *E. strobilacea* type is reflecting the soils with considerable amount of gypsum. The types of *S. rosmarinus* and *H. phyllum* are directly related to pH and lime percentage, while *A. aucheri–As. sp.* type shows an inverse relation with these factors.

Totally, each plant species has specific relations with environmental variables. These relations are because of habitat condition, plant ecological needs and tolerance range. Understanding the indicator of environmental factors of a given site leads us to recommend adaptable species for reclamation and improvement of that site and similar sites.

This study provides fundamental data of biotic and abiotic components in this region. Understanding relationships between environmental variables and vegetation distribution in this area helps us to apply these findings in management, reclamation, and development of arid and semi-arid grassland ecosystems. Sustainable and integrated management practices, including using grazing system and manipulation of plant species (density and cover) and monitoring environmental variables dynamics, should be applied.

Appendix A

Units and abbreviations of the vegetation types and environmental factors in the figures and tables :

Artemisia acheri–Astragalus sp.	*Ar.au–As. sp.*
Artemisia sieberi	*Ar. si*
Ephedra strobilacea	*Ep. st*
Cornulaca monocantha	*Co. mo*
Haloxylon aphyllum	*Ha. ap*
Seidlitzia rosmarinus	*Se. ro*
Tamaerix ramosissima	*Ta. ra*
Dorema ammoniacum	*Do. am*
Stipa barbata	*St. ba*
Salsola rigida	*Sa. ri*
Eigenvalue	Eign
Elevation (m)	abs
Slope (%)	slope
Gravel (%)	gr
Clay (%)	clay
Silt (%)	Lo
Sand (%)	sa
Saturation moisture (%)	sm
Gypsum (%)	gy

Lime (%)	Li
pH (acidity)	pH
ECe (ds/m)	EC
Sodium ion (Na^+) (meq/l)	Na
Potassium ion (K^+) (meq/l)	K
Calcium ion (Ca^{2+}) (meq/lit)	Ca
Magnesium (Mg^{2+}) (meq/l)	Mg
Chlorine (Cl^-) (meq/l)	Cl
Carbonate (CO_3^{2-}) (meq/l)	CO
Bicarbonate (HCO_3^-) (meq/l)	HC
Sulfate (SO_4^{2-}) (meq/l)	SO
Sodium absorption ratio (SAR)	SAR

Code 1 is related to the soil characteristics were measured in the first layer (0–30 cm).

Code 2 is related to the soil characteristics were measured in the second layer (30–60 cm).

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