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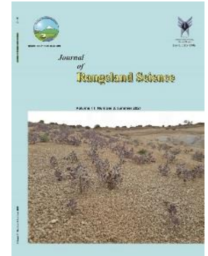

Research and Full Length Article:

# Correlations between Some Vegetation Attributes and Soil Physicochemical Properties at Selected Wet Season Grazing Sites Central Sudan

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**Abstract**: This study aimed to trace changing patterns of vegetation attributes in association with soil physicochemical properties at selected seasonal grazing sites central Sudan (Khartoum State) namely Tundub, El-Farish, Abuseweid, Medaisees, Buhat, Abudolou'a Km 72 and Abudolou'a Km 42. A combination of sampling procedures was followed to sample vegetation and soil. Comparisons between sites were made using one way ANOVA, followed by Duncan's Multiple Range Test (DMRT). Pearson's correlation analysis was made between plant attributes and soil physicochemical properties. Study sites varied significantly in plant productivity, diversity and soil properties. Abuseweid site achieved the highest herbaceous diversity, density and total dry matter productivity values. Tundub and Buhat were higher in woody perennial attributes having the highest browse productivity and percentage canopy covers. Tundub exceeded other sites in plant ash, Ca, Mg and K contents followed by Medaisees every time. Medaisees exceeded others in plant P and N contents, given that Tundub, Medaisees and Buhat were higher in perennial woody attributes. The sand dune sites Abudolou'a Km 42 and Km 72 were the poorest sites in all vegetation attributes measured. Variation between sites in plant attributes was strongly related to variation in soil physical and chemical properties. Two groups of soil physicochemical factors regarding their associations with vegetation attributes were observed, soil Na, N, clay, water holding capacity (WHC), EC, OC, OM and silt contents were positively correlated to vegetation attributes; pH, Ca and sand contents negatively correlated to vegetation attributes.

**Key words:** Correlations, Rangelands, Plants variables, Soil parameters

## Introduction

Rangelands provide protection of soils from erosion and desertification, restoration of organic and mineral nutrients, absorption of $CO_2$, habitats to wildlife and soil microbial communities and fodder to livestock in addition to many other values. Soil is a reservoir of plant nutrients and greatly varies with their distribution in time and space due to changes in chemical characteristics (Awe *et al*., 2007) and Plant development and growth depend largely on the combination and concentration of mineral nutrients available in the soil (Ogidi *et al*., 2018). If the balance of inorganic nutrient (among other requirements) is optimum, the growth of plants and therefore the yield of harvests depends on the soil physical and chemical properties as well as upon the chemical composition of the inorganic and organic soil constituents. Minerals play a unique role in animal nutrition because they are essential for the utilization of energy and protein biosynthesis (McDowell, 1992). There is a specified minimum limit of every complex (organic) and mineral nutrient required for growth, maintenance, repair, rumen microbial activities and other physiological functioning of grazing animals (van Soest, 1982; Milford and Haydock, 1965). Plant nutrient contents reflect nutrient availability in the soil which are also major limits to productivity in semi arid ecosystems (Suzanne *et al*., 2012) and Leakage of these scarce resources can limit the functional capacity of soils and landscapes to support plant growth and can ultimately lead to ecosystem desertification (Ludwig *et al*., 1997; Field *et al*., 2009). Vegetation attributes (DM productivity, coverage, species diversity, richness, composition and nutritional values of rangeland plants are good indicators of rangeland condition (Friedel *et al*., 2000). They are widely used by rangeland management authorities worldwide as inventory, monitoring and assessment tools and as baseline information acquired for the evaluation and decision making to maximize productivity quantitatively and qualitatively for sustainable utilization of rangelands. Many models, techniques and methods to define, assess and evaluate rangeland condition and health exist (Tongway *et al*., 1995; Westoby *et al*., 1989; Holling, 1973; Payne *et al*., 1970; Speck *et al*., 1960; Humphery, 1949). Most of them employed vegetation attributes to define, diagnose and evaluate rangeland condition and health and to specify stocking rates with little emphases on soil structure and nutrient contents and their relatedness to plant productivity, diversity and nutrient contents with only soil erosion magnitudes have been taken into account. Our current knowledge about patterns of nutrient resorption, particularly among herbaceous species, at a global scale is still inadequate. Nutrient resorption (i.e., internal nutrient recycling) is recognized as one of the most important mechanisms in plant ecology because it permits plants to re-use nutrients directly and reduces their dependence on external nutrient supplies, especially in nutrient-poor environments (Aerts and Chapin, 1999). Relating soil physical and chemical properties especially nutrient concentrations to yield and crop quality was studied intensively in the field of agriculture and fertilizer applications (Watros *et al*, 2018; Mirzakhaninafchi *et al*, 2017), but little such studies were found in rangelands and natural vegetation studies. Many ecological evaluation of rangelands and natural vegetation studies involved analyses of soil and plant samples for determining of nutrient concentrations either for judgment on site or ecosystem status, for comparative purposes or to examine the effects of grazing intensity on soil properties (Sandhage-Hofmann *et al*., 2015; Thomas *et al*., 2015). In this study we try to make an insight to alternating influences between soil physicochemical properties on one side and some vegetation attributes and plant mineral contents on the other side. It is an attempt to trace how productivity, diversity, cover and nutrient contents of rangeland plants change following variation in soil conditions from site to site and what patterns of variability exist. Understanding of such relationships will help in outlining site specific needs, and limits of providing fodder of specific quality and, in turn, assist in determining rangelands' carrying capacities and stocking rates.

## Materials and Methods

### The Study Area

The study area falls within the semi-arid part of Sudan that covers an area of 492,098 $Km^2$. Rainfall ranges from 75 to 300mm which extends from July to September (Zahran, 1982). The study area belongs to Khartoum State which is divided by the River Nile (Main Nile, White Nile and Blue Nile) into two parts namely Eastern Nile and Western Omdurman. According to the Comprehensive Agricultural Census of 2009, area of the State occupied by natural rangelands and forests was estimated by 2.10 M ha. More than 1384000 heads of livestock are found in the state, of which, 24000 are cattle (17%), 7000 camels (1%), 513000 sheep (37%) and 624000 goats (45%). Agro-pastoral activity in the Eastern Nile as well as the Northwestern parts far from the River Nile of Khartoum state is mostly dependent on the amount, distribution and durations of rainfall. The state is characterized by the hot summer climate with only the months of July and August experiencing significant precipitation with an average a little over 155mm per year.

### The study sites

A total of seven grazing sites were selected for the study, three lowlands (*wadies*) in the Eastern part of the study area namely Wadi Tundub (denoted by T in this study) (15° 42.330″ N, 033° 6.278″ E) (about 71Km to the East from the Blue Nile), Wadi Elfarish (F) (15° 42.289″ N, 033° 6.283″ E) (about 70 Km from the Blue Nile) and Wadi Abuseweid (A) (15° 37.133″ N, 032° 55.005″ E) lies on the most Eastern part and represents the Western edge of Butana region; and four sites (two lowlands and two sand dunes) in the Northwestern part, Wadi Medaisees (M) lies on the Northwestern part of Khartoum state (16° 12.223' N, 31° 41.392' E), Wadi Buhat (B) 16° 20.395' N, 31° 48.686' E, it is a part of Wadi El Mugaddam at Buhat village (about 108 Km Northwestern Omdurman), Qoz Abu Dolou'a Km 72 (sand dune) (Q72) (16° 11.234′ N, 31° 49.258′ E) extends up to nearly Km 110 along Shririan El Shimal highway to the North. The highway divides the Qoz into two Eastern and Western portions; and Qoz AbuDolou'a Km 42 (Q42) (sand dune) (16° 09.275′ N, 31° 49.317′ E).

### Vegetation Sampling Methods

A combination of systematic, non-random and random sampling procedures (Greig-Smith, 1983) was employed in this study in the sense that the sampling sites were selected non-randomly based on local knowledge about the most important grazing sites where both activities cultivation and grazing prevail during the rainy season. A metal 1× 1m quadrate for herbaceous sampling was used. Five quadrates were found to be enough to include all herbaceous species in each site according to the species – area curve method (Barbour, 1987). 20m x 20m plots for woody vegetation sampling were used. Quadrates and plots were located randomly along a line transect established parallel to the lowland direction of flow or sand dune extension.

### Density of herbaceous species

Density of herbaceous species was measured within 1m x 1m quadrate; individuals of each species were counted, every individual rooted within the quadrate was considered, and the species present in each quadrate were recorded with their numbers of individuals. Species not identified in the site were pressed and coded to be identified later by specialists or references. Total number of individuals from all species/m$^2$ were recorded for the 5 quadrates at each site.

### Total Dry matter productivity

While counting the number of individuals per species within each 1m x 1m quadrate, the individuals were clipped to the ground level separately from individuals of other species and located into a paper bag, fastened and labeled with the species name, quadrate number, site and date and kept to be dried in shade. After drying, total dry weight of all species/m$^2$ was measured using a sensitive balance for the 5 quadrates and at each site.

### Browse productivity

Biomass production of woody species was estimated using the Twig Count Method of Bobeck, and Bergstorm (1978).

### Canopy cover

Canopy cover was measured using the method described by Husch *et al*, (1986). In this method, the crown diameter of each tree within the (20m x 20m) plot was measured by stretching a meter tape on the ground. The start/end points of measurements were adjusted to the outermost edges of the crown with the tape passing tangent to the tree stem. Then the crown diameter was measured again in the same way but in a direction perpendicular to the first one. The two measurements were recorded as diameter 1 (D1) and diameter 2 (D2). Then the crown cover (CC) for each tree was calculated using the following equation:

$$CC = \frac{D1+D2}{4} \times \pi^2$$

Then the crown covers of all trees of each species within the plot were summed and the percentage of the plot area covered by tree crowns of that species was calculated as:

$$\%\,Woody\ species\ cover = \frac{total\ crown\ covers\ of\ that\ species}{plot\ area} \text{ x } 100\%$$

### Herbaceous species diversity

Herbaceous species recorded were listed with their total numbers of individuals (in rows) in each site (columns) and entered to the Paleontological Statistics (PAST) software version (Past326b) and Shannon_H diversity values of different sites were obtained.

### Determination of plant's mineral contents

A total composite sample from each study site was collected to be used in the determination of mineral content of the site vegetation. Determination of mineral content was carried out in the laboratory of soil, Faculty of Agriculture, University of Khartoum according to the procedures described in AOAC, (1990).

### Soil sampling and analysis

Nine soil samples from three randomly selected points within each site (three depths each), (0-30cm, 30-60cm and 60-90cm) were taken. Soil from similar horizons was carefully mixed and about 1Kg sub sample was collected and kept in a high density plastic bag and labeled with the site and depth. Soil samples were then transferred to the soil laboratory of the Faculty of Agriculture, University of Khartoum for the determination of physical and chemical properties following procedures described in Anonymous, (1992) and average values of soil parameters from the three depths were maintained.

### Statistical Analysis

One Way (ANOVA) was employed to test the differences between sites in herbaceous

DM productivity, browse production and total herbaceous density as this design is suitable when environmental conditions are not under control. Analysis of variance was carried out according to Gomiz and Gomiz, (1986). Means were separated using the Duncan's Multiple Range Test (DMRT), (Duncan, 1955). Pearson's correlations between vegetation measures (h. DM productivity, herbaceous diversity (Shannon_H), browse production, herbaceous density, % woody cover and nutrient contents) against soil parameters; between plant mineral contents and soil parameters were maintained from the Paleontological Statistics (PAST) software version (Past326b) and plotted to visualize and highlight correlations between different factors, between +1 (strong positive) and -1 (strong negative) with significant correlations (p< 0.05) boxed.

## Results

### Comparison between sites for rangeland productivity and diversity

Comparison between sites for herbaceous dry matter productivity (Kg/ha), browse productivity (Kg/ha), herbaceous density (No/m$^2$) and harbaceous diversity showed significant differences ($p < 0.05$) (Table 1). For site A, the highest herbaceous DM productivity, herbaceous density and herbaceous diversity values were obtained. While, sites Q42 and Q72 showed the lowest values of all vegetation attributes tested except the Shannon diversity index which was found to be lowest at site B. Site T exhibited the highest browse productivity followed by B which also obtained the highest percentage woody canopy cover. Generally it can also be easily observed that sites A, F and M exceeded others in herbaceous attributes while site T and B exceeded in perennial woody vegetation attributes (Table 1).

**Table 1.** Mean herbaceous dry matter productivity (kg/ha), browse productivity (Kg/ha), total herbaceous density (total No of indiv./m$^2$), % woody cover and Shannon_H diversity at different sites.

| Site Code | Name of Study Sites | Herbaceous DM productivity (Kg/ha) | Browse productivity (Kg/ha) | Herbaceous Density (No/m$^2$) | Woody Cover % | Shannon_H diversity |
|---|---|---|---|---|---|---|
| T | Tundub | 653.00 $^{c}$ | 37.50 $^{a}$ | 835.40 $^{c}$ | 49.61 | 0.832 |
| F | El-Farish | 1154.6 $^{b}$ | 13.69$^{cd}$ | 1355.4 $^{ab}$ | 19.48 | 1.469 |
| A | Abuseweid | 1705.8 $^{a}$ | 18.82 $^{bc}$ | 1396.6 $^{a}$ | 48.60 | 1.541 |
| M | Medaisees | 1118.8 $^{b}$ | 20.00 $^{abc}$ | 887.00 $^{c}$ | 17.92 | 1.139 |
| B | Buhat | 512.8 $^{cd}$ | 28.94$^{ab}$ | 1278.6 $^{ab}$ | 89.41 | 0.088 |
| Q72 | Abudolou'a Km 72 | 1234.0 $^{b}$ | 2.88 $^{d}$ | 128.80 $^{d}$ | 3.76 | 0.345 |
| Q42 | Abudolou'a Km 42 | 230.4 $^{cd}$ | 0.75 $^{d}$ | 41.60 $^{d}$ | 4.44 | 1.079 |
| ±SE | | 91.96 | 4.93 | 37.84 | 11.73 | 0.206 |

Values within columns bearing different superscripts vary significantly at P <0.05.

### Comparison between sites for soil properties

Soil reaction (pH) of all sites was found to be slightly alkaline (above 7.00) (Table 2), with sites Q42 and Q72 having the highest values. Site A obtained the highest soil water holding capacity (WHC) value, while sites Q42 and Q72 exhibited the lowest ones. Site T obtained the highest soil electrical conductivity (EC%), Ca% and Mg% which were the lowest at Sites M and A respectively. Soil Na% was highest at site M and lowest at site B. Site A also obtained the highest soil N% which was the lowest at site B and organic carbon (OC%) which was the lowest at site T. Soil organic matter (OM%) was found to be the highest at site B and the lowest at site Q42; soil $CaCo_3$ was the highest at site M and the lowest at site A. Soil sand content (%) was the highest at sites Q42 and

Q72 and the lowest at site F; soil silt and clay contents were the highest at sites M and A respectively and the lowset at sites Q42 and Q72.

**Table 2.** Soil chemical composition and physical properties of the study sites

| Site | SP% | pH | WHC% | EC% | Ca% | Mg% | Na% | N% | OC% | OM% | CaCO3% | Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | 43.25 | 7.37 | 21.67 | 0.68 | 3.80 | 1.92 | 1.13 | 0.47 | 0.05 | 0.11 | 5.03 | 34.33 | 19.59 | 39.47 |
| F | 45.73 | 7.28 | 25.33 | 0.64 | 3.67 | 1.33 | 1.23 | 0.57 | 0.07 | 0.12 | 5.00 | 30.47 | 24.33 | 45.20 |
| A | 39.33 | 7.49 | 44.54 | 0.35 | 1.60 | 0.53 | 1.43 | 0.87 | 1.03 | 0.31 | 4.37 | 45.70 | 8.9 | 45.43 |
| M | 44.40 | 7.41 | 40.13 | 0.62 | 1.50 | 1.83 | 1.50 | 0.80 | 0.78 | 0.23 | 9.67 | 36.40 | 24.60 | 39.00 |
| B | 36.50 | 7.31 | 41.73 | 0.55 | 2.13 | 1.77 | 0.87 | 0.03 | 0.92 | 0.41 | 7.83 | 44.87 | 22.33 | 33.13 |
| Q72 | 40.31 | 7.51 | 20.13 | 0.21 | 3.13 | 1.10 | 1.00 | 0.16 | 0.06 | 0.13 | 5.10 | 62.34 | 8.91 | 28.75 |
| Q42 | 41.37 | 7.53 | 18.74 | 0.27 | 3.05 | 0.99 | 0. 98 | 0.11 | 0.08 | 0.10 | 4.84 | 59.96 | 8.40 | 31.64 |
| Mean | 36.80 | 6.49 | 27.06 | 0.42 | 2.40 | 1.20 | 1.02 | 0.39 | 0.39 | 0.18 | 5.32 | 39.84 | 14.99 | 33.13 |
| ±SE | 3.576 | 0.037 | 4.271 | 0.072 | 0.359 | 0.194 | 0.089 | 0.127 | 0.172 | 0.045 | 0.749 | 4.689 | 2.891 | 2.479 |
| C.V | 37.34 | 40.20 | 51.49 | 53.88 | 50.23 | 52.08 | 42.62 | 84.43 | 109.59 | 68.26 | 48.92 | 45.85 | 57.39 | 41.63 |

## Correlation between plant productivity and soil physicochemical properties

Table 3 shows that herbaceous DM productivity had significant positive correlations with soil N, Na, and clay contents. Browse productivity had positive significant correlations with soil EC, Mg and silt contents and negative significant correlations with soil pH and sand contents. Herbaceous density was found to be significantly positively correlated to soil WHC, EC, OC, OM, silt and clay contents, while significantly negatively correlated to soil pH and sand contents. Significant positive correlations were also found between percentage woody cover and soil WHC, OC and OM contents. Shannon diversity index had significant positive correlations with soil Na, N and clay contents. Figure 1 highlights the most effective correlations between rangeland productivity and soil physicochemical properties. It shows that browse productivity had significant positive correlations with soil WHC and EC; herbaceous total density had a significant positive correlation with soil clay and a significant negative correlation with soil sand content. % WC was most positively correlated to soil OM, while herbaceous diversity was most positively correlated to soil Na, N and clay contents.

**Table 3.** Pearson's correlations between herbaceous total dry matter productions, browse production, herbaceous density, %woody cover, Shannon_H diversity index and soil physicochemical properties.

| Traits | Herbaceous DM productivity (Kg/h) | Browse productivity (Kg/h) | Herbaceous Density (No/m$^2$) | Woody Cover % | Shannon_H Diversity |
|---|---|---|---|---|---|
| pH | 0.11 | **-0.61*** | **-0.69*** | -0.52 | 0.08 |
| WHC% | 0.42 | 0.40 | **0.71*** | **0.60*** | 0.10 |
| EC% | -0.10 | **0.77*** | **0.62*** | 0.41 | 0.13 |
| Ca% | -0.36 | -0.06 | -0.31 | -0.27 | -0.07 |
| Mg% | -0.45 | **0.64*** | 0.12 | 0.32 | -0.43 |
| Na% | **0.69*** | 0.13 | 0.41 | -0.20 | **0.76*** |
| N% | **0.72*** | 0.24 | 0.53 | -0.09 | **0.78*** |
| OC% | 0.35 | 0.34 | **0.60*** | **0.60*** | 0.02 |
| OM% | 0.16 | 0.40 | **0.60*** | **0.79*** | -0.28 |
| CaCO3% | -0.13 | 0.29 | 0.17 | 0.22 | -0.29 |
| Sand% | -0.17 | **-0.70*** | **-0.76*** | -0.34 | -0.39 |
| Silt% | -0.11 | **0.59*** | **0.56*** | 0.34 | -0.03 |
| Clay% | **0.55*** | 0.39 | **0.78*** | 0.17 | **0.79*** |

*****=Significant at 5% probability level.

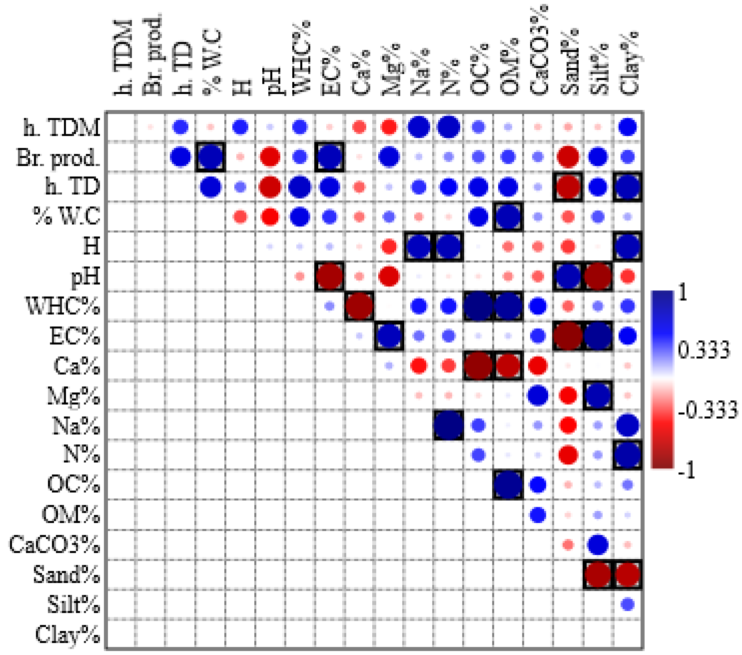


**Fig. 1.** Pearson's correlations (plotted) between herbaceous total dry matter productions, browse production, herbaceous density, %woody cover, Shannon_H diversity index and soil physicochemical properties

## Correlation between plant minerals contents and soil physicochemical properties

Correlations between plants minerals contents and soil physicochemical properties were shown in table 4. Plant ash content had significant positive correlations to soil EC, Mg and silt contents and significant negative correlation to soil sand contents. Plant Ca content had significant positive correlations to soil EC and Mg and a significant negative correlation to soil sand content. Plant Mg content had significant positive correlations to soil EC, Mg and $CaCO_3$ contents. Plant K content had significant positive correlations with soil WHC, EC, Na, N, $CaCO_3$, silt and clay, while it had significant negative correlations with soil sand content. Plant P content was significantly positive correlated to soil Na and $CaCO_3$. A significant negative correlation between plant OC content and soil Mg was also observed. Significant correlations between plant minerals contents and soil physicochemical properties were plotted and boxed in figure 2. Soil EC and Mg were shown to be the most positively related to plant ash and other minerals contents; plant K had significant positive correlation with soil Na and also plant P with soil $CaCO_3$. Sand content was found to be negatively related to plant minerals contents.

**Table 4.** Pearson's correlations between plant minerals and soil physicochemical properties.

| Traits | Ash% | Ca% | Mg% | K% | Na% | P% | N% | OC% |
|---|---|---|---|---|---|---|---|---|
| pH | -0.50 | -0.17 | -0.29 | -0.37 | 0.22 | -0.06 | -0.13 | 0.23 |
| WHC% | 0.13 | 0.04 | 0.04 | **0.57*** | -0.28 | 0.39 | 0.06 | 0.15 |
| EC% | **0.84**** | **0.64*** | **0.69*** | **0.72*** | 0.07 | 0.36 | 0.25 | -0.53 |
| Ca% | 0.08 | -0.03 | -0.07 | -0.47 | 0.35 | -0.54 | -0.14 | -0.23 |
| Mg% | **0.78*** | **0.66*** | **0.73*** | 0.48 | -0.01 | 0.38 | -0.04 | **-0.69*** |
| Na% | 0.30 | 0.48 | 0.41 | **0.77*** | 0.02 | **0.67*** | 0.57 | -0.19 |
| N% | 0.35 | 0.46 | 0.34 | **0.74*** | 0.14 | 0.53 | 0.47 | -0.21 |
| OC% | 0.05 | -0.02 | -0.02 | 0.47 | -0.25 | 0.33 | -0.03 | 0.21 |
| OM% | 0.00 | -0.20 | -0.18 | 0.25 | -0.31 | 0.09 | -0.25 | 0.24 |
| CaCO3 | 0.38 | 0.45 | **0.64*** | **0.65*** | -0.52 | **0.80**** | 0.26 | -0.26 |
| Sand% | **-0.74*** | **-0.55*** | **-0.57*** | **-0.75*** | -0.08 | -0.35 | -0.37 | 0.42 |
| Silt% | **0.65*** | 0.48 | **0.65*** | **0.66*** | -0.30 | 0.48 | 0.35 | -0.40 |
| Clay% | 0.35 | 0.24 | 0.17 | **0.58*** | 0.17 | 0.17 | 0.44 | -0.03 |

*and ** =Significant at 5% and 1% probability levels, respectively

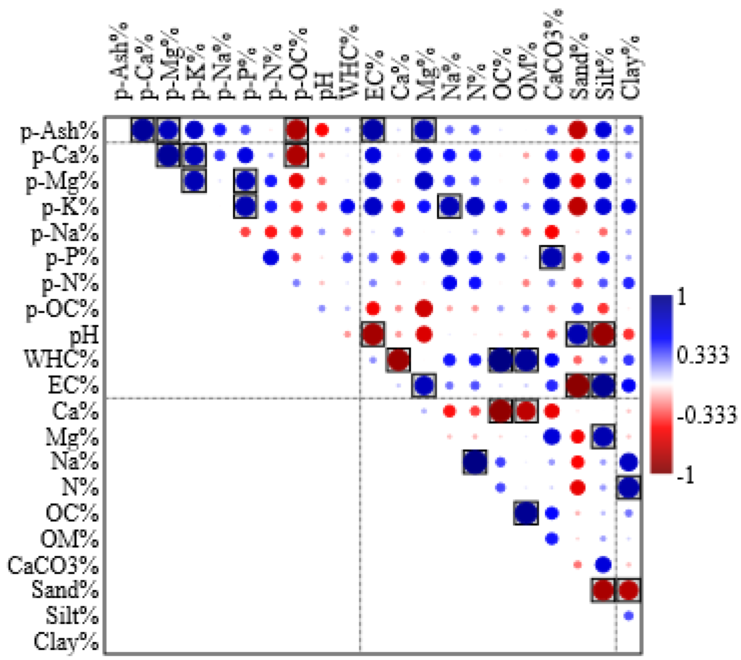


**Fig. 2.** Pearson's correlations (plotted) between plant minerals / soil physicochemical properties

## Discussion

Association patterns between plant productivity, density, diversity and coverage with soil physicochemical properties obtained in this study generally were positive to soil N, OC, WHC and clay and negative to sand contents. Many previous studies partially reported similar results. Wen-Feng *et al*, (2019) reported that increased nutrient levels enhanced herbage yield. Nutrient availability shapes the composition, diversity and productivity of grasslands (Grime, 2002; Tilman, 1988). Dybzinski *et al.*, (2008) explained the production of more biomass by greater soil N availability, inputs, and retention. Soil with high organic matter and aggregates can absorb and hold water during rainfall events and deliver it to plants during dry spells (Bhadha *et al*., 2017). Karyati et al., (2018) also clarified the correlation among most important soil properties, floristic structure parameters, and floristic diversity indices. Sites Q42 and Q72, which are sand dune formations, were found to be the poorest sites in almost all of rangeland productivity measures investigated. This is mostly probably due to the high sand ratios over silt and clay in their soils and low organic material contents (given the negative correlations between sand, OC and OM (Fig. 1), leading to low microbial communities and decomposition activities and decreased soil fertility in general. Abdullah *et al*., (2017) studied Cholistan rangeland of Pakistan, a hot desert and concluded that the browse productivity was low. Relationship between browse productivity and soil pH was reported by Glumac *et al*, (1987) that soil pH negatively correlated to biomass. Also Chakraborty (2016) stated that to maintain productivity of crop, desired pH level is 6 to 7 in soil, the statement which agrees with findings in this study. He also argued that soil pH is considered as master variable as it controls physical, chemical and biological properties of soil. Differences between rangeland sites in species diversity was justified by Duran (2013) who stated that differences in parent material and soil types play an important role in determining the diversity and distribution areas of plant communities. Result regarding the association between diversity and soil N is the same as that reported by Martin *et al*. (2015) that Shannon-Wiener diversity was positively correlated to C/N ratio and herb structural richness was positively correlated with soil fertility index. Therefore, herb structural richness may be a good indicator of soil fertility. Plant ash, Ca, Mg and K showed positive correlations to soil EC, Mg, Na and N contents. Significant positive correlations ($P < 0.01$) were reported by Ogidi *et al*., (2018) between soil Mg, soil OM and total N, available P, exchangeable K; leaf N, Ca and P contents.

## Conclusion

The study sites varied significantly in rangeland plant productivity, biodiversity, plant mineral contents and soil physicochemical properties. Variation between sites in vegetation attributes tested was found to be strongly related to soil properties. Soil WHC, N, OC and clay contents were the most positively correlated to herbaceous attributes, while soil EC, Ca and Mg were the most soil factors positively related to browse attributes. Soil sand contents exhibited negative relationships to both plant productivity and diversity as well as plant mineral contents.

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