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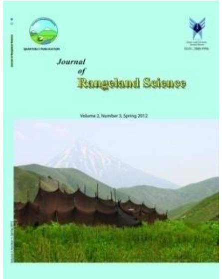

Full Length Article:

Multivariate Statistical Method for Assessing Livestock Grazing Effects on Soil and Vegetation in Steppe Rangelands (Case Study: Steppe Rangelands of Saveh)

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Abstract. This study aims to assess the effect of grazing intensity on vegetation structure, soil nutrient concentrations and soil physical properties. The study was carried out in steppe rangelands of Saveh, Markazi province, Iran. Four sites with four grazing intensities including very high, high, moderate and non-grazed with the same ecological conditions were selected. To study various vegetation and soil parameters in each range site, a reference area was selected. Then, sampling was performed by randomized systematic method in reference areas. Vegetation characteristics, soil physical properties, bulk density, infiltration rate, soil texture and chemical constituents including nitrogen, phosphorus, potassium, pH, EC and organic carbon were measured. Principal component analysis was performed on a dataset with 22 variables to determine the effect of grazing intensity on vegetation structure and soil properties. Results indicated that the first three axes explained the total variation. The variables of potassium, phosphorous, bulk density, class I, class II, clay, field capacity, infiltration, *Peganum harmala, Salsola laricina*, *Artemisia sieberi* and perennial forbs had significant correlations with the first axes and explained a 74.27% variation. For the second components, silt, sand and perennial grasses were more important traits and explained a 15.5% variation. In non-grazed and moderate grazed sites, there were more canopy cover of both *Artemisia sieberi* and *Salsola laricina*, and for high grazing sites, there were plants of class III such as *Noaea mucronata* and *Peganum harmala*. The grazing intensity was associated with lower values of infiltration, clay percent and field capacity and higher values of bulk density, potassium, phosphorous and sand percent. Therefore, vegetation structure and soil properties were changed by the interaction between grazing intensity, soil properties and vegetation structure. The results suggested that excluding grazing livestock on the arid steppes has a great potential to restore vegetation and soil. Therefore, it must be encouraged as an alternative to stop further degradation and to combat desertification in arid and semi arid ecosystems.

Key words: Grazing intensity, Soil, Vegetation, Arid and semi-arid rangelands, Principal Component Analysis (PCA).

Introduction

Rangelands with great economic and social values for rural and nomads community livelihood have undergone many stresses during the past three decades due to excessive grazing pressure. Rangeland degradation can face local communities with deep crises (Mesdaghi, 2004). Rangeland soil is the source of nutrient and moisture for rangeland plants. Over grazing is the most significant factor causing degradation of vegetation and soil in a rangeland. The impact of livestock grazing on rangeland is considered to be in three processes: the loss of plants due to foraging, soil and litter trampling and deposition of urine. The effects of these processes are hardly distinguishable from each other (Hiernaux *et al.,* 1999). Heavy grazing leads to excessive defoliation of herbaceous vegetation, reducing standing biomass, basal cover and plant species diversity often triggered by a decline in Net Primary Productivity (NPP) as the intensity of grazing increases (Bilotta *et al.,* 2007).

Effects of grazing intensity on rangeland vegetation and soil had been described by several studies (Wang and Ripley, 1997; Wang, 2004; Li *et al.*, 2008). There is no unanimity among the authors on the effects of grazing intensity on soil properties which can be related to different climatic and edaphic conditions, vegetation type, management strategy and livestock type. Several studies reported that livestock grazing can improve nitrogen cycling through the stimulation of N mineralization and direct deposition of waste. Furthermore, livestock grazing can decrease nitrogen cycling by the reduction of N-rich plant species and increase of N-poor plant species (Shan *et al.,* 2011). Xie and Wittig (2004) stated that increasing the grazing intensity reduced soil organic matter and nitrogen, but the pH value and potassium were not significantly affected by grazing in the steppes of northern China. Tessema *et al.,* (2011) in a semi-arid savanna of Ethiopia concluded that the concentration of total nitrogen was higher in sites with light grazing as compared with sites exposed to heavy grazing. Similarly, higher concentrations of K, C and Na were observed in sites under light grazing.

Various studies have applied Principal Component Analysis (PCA) to assess the effect of livestock grazing on rangeland ecosystem components (Dumont *et al.,* 2009; Kohandel *et al.,* 2011; Zheng *et al.,* 2011). Kohandel *et al.,* (2011) stated that grazing intensity caused an increase in the density of broad leaves plants (forbs) whereas densities of grasses and shrubs were decreased. The study also found that soil porosity and penetration resistance were decreased with the increase in grazing intensity. They observed that pH, EC and K had the highest relationships with grazing intensity. In France, Dumont *et al.,* (2009) observed that plant species richness and evenness were associated with the intermediate stocking rate. In addition, competitive grasses and forbs were associated with soil fertility and with the N concentration of the herbage. Heavy grazing had a negative impact on the grass layer, reducing the water and nutrient uptake by the grass layer, thus making more resources available for woody growth and this may result in an encroachment of shrubs (Skarpe, 1991).

Zheng *et al.,* (2011) indicated that *Cleistogenes squarrosa* is more resistant to grazing than *Leymus chinensis* in terms of avoidance and tolerance traits, particularly under heavy grazing intensity and in the dry year. In overall, evaluating the effects of livestock grazing is essential to achieve proper management in rangeland ecosystems. The goal of this study was to determine the effect of livestock grazing intensity on selected soil physical and chemical properties and vegetation structure in the steppes of central Iran.

Materials and Methods

Study area

This study was conducted at the steppe rangelands of Saveh, 60 km of Saveh, Markazi province, Iran (Fig. 1). The study area lies between 50° 35' 49" and 50° 49' 11" E longitudes and 35° 23' 46" and 35° 30' 55"N latitude. Mean annual temperature and precipitation of the study area were 19°C and 200 mm and mean monthly temperature range from 4.5 °C in January to 32.6 °C in July with

51–89% occurring in the growing season (March– June), respectively. Topography wasconsisted of both slope and flat terrain. The average altitude was 1325 m above sea level. Soil texture is sandy clay loam.

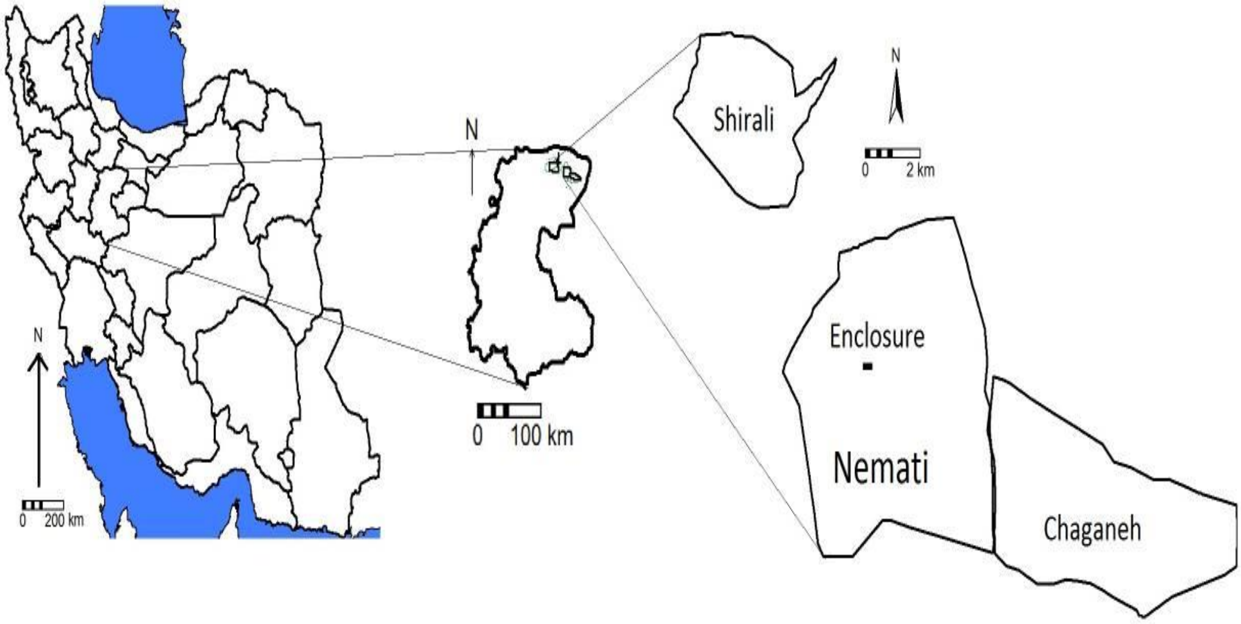

Fig. 1. Location of study area in Iran

Experimental design and grazing treatment

Three range sites including Nemati, Chaganeh and ShirAli with different grazing intensities, vegetation type and management strategies were selected in the study area.

a. Nemati range is a winter rangeland and grazed under rotational grazing system with moderate stocking rate (state AU) during last 10 years. Sagebrush (*Artemisia sieberi*) and saltwort (*Salsola laricina*) were dominant plant species. Grazing period started in mid-May till early November.

b. Chaganeh range is a winter rangeland and grazed under continuous grazing system for 6 months with high stocking rate (state AU). Sagebrush *(Artemisia sieberi*) and saltwort *(Salsola laricina*) were dominant plant species. Grazing period started in mid-May till early November.

c. ShirAli range is grazed continuously all the year with very high stocking rate (state AU). *Noaea mucronata* and *Cousinia cylindracea* were dominant plant species.

d. Exclosure area: This area located within the borders of Nemati rangeland has been enclosed for 4 years.

Measurement of vegetation structure and soil properties

To study various vegetation and soil parameters in each range site, a reference area was selected. In the next step, sampling was performed by randomized systematic method in reference areas. As 60 (2 m^2) plots were established along four transects of 400 m long with 100 m intervals.

However, in ShirAli, the number and space of plots and transects were less depending on the surface area of the region. Canopy cover percentage of the species was measured in each plot. Also, 15 soil samples were taken at the depth of 0-20 cm randomly along transects. Soil samples were dried in an oven at 105 °C for 24 h and then ground and passed through a 2 mm sieve to get 2 mm fractions. Soil chemical properties including Organic Carbon (OC), total Nitrogen (N), total Phosphorus (P), potassium (K), pH and EC were measured. The OC% was determined according to the Walkley and Black (1934) method and total N was determined using the Kjeldahl procedure (Bremner and Mulvaney, 1982). Available Phosphorus (P) was analyzed according to Olsen *et al.*, (1954).

Soil potassium (K) content was determined by normal ammonium acetate method. Soil pH and Electrical Conductivity (EC) were determined saturated paw method, (AFNOR, 1987) by pH meter and conductivity meter, respectively. Bulk density was determined by clod method (Kim, 1995). Double ring infiltrometers consisting of two concentric rings with inner and outer diameters were used to measure the infiltration rate following the procedure described by Bouwer (1986). Sand, silt and clay proportions of soil samples in the laboratory were determined with the hydrometer method (Bouyoucos, 1962).

Data analysis

For soil properties, 13 traits as N, K, P, bulk density, clay, FC, infiltration rate, porosity, OC, EC, sand, pH and silt and for vegetating structure, 9 traits were determined for class I, class II, class III, *Salsola laricina*, *Artemisia sieberi*, *Noaea mucronata*, *Peganum harmala*, Perennial grass and Perennial forb.

To describe the relationships between vegetation structure and soil properties with grazing intensity, data were analyzed using Principal Component Analysis (PCA) and PC-ORD software.

Principal component analysis which is a line method and coordinates of sample unit is determined by a linear combination of weighed parameters in a special new axis. If data have no linear relationships, this method cannot show a relationship between sample units and needs not much precision to apply it (Moghddam, 2001). To apply PCA, data standardization is necessary if we are analyzing variables measured in different units. Data were centered and standardized by standard deviation. Eigen values for each principal component were compared to a broken–stick eigenvalue to determine whether the captured variance summarized more information than expected by chance. Broken-stick eigenvalue has been shown to be a robust method for the 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 (Zare Chahouki *et al.,* 2012)

Results and Discussion

According to the results of PCA analysis, the first three axes explained total variation (100%) (Table 1). For the first components, K, P, Bulk Density (BD), class I, class II, clay, FC, infiltration rate, *Salsola laricina, Artemisia sieberi*, *Peganum harmala* and perennial forbs had significant correlations with the first axis and explained a 74.27% variation. For the second components, sand, silt and perennial grasses were important traits and explained a 15.5% variation and finally, for third components, pH, EC, OC and class II explained a 10.22% variation (Tables 1 and 2).

Table 1. Principal components and explained variances of each axis

AXIS (Component)	Eigen Value	% Of Variance	Cum. (%)	Broken-Stick Eigen Value
1	16.34	74.27	74.27	3.69
2	3.41	15.5	89.77	2.69
3	2.24	10.22	100	2.19

Table 2. Results of principal component analysis on soil properties and vegetation structure

Variable	AXIS		
	1	2	3
Potassium (K)	**0.241**	0.101	0.097
Phosphorus(P)	**0.223**	-0.230	0.029
Bulk Density	**0.231**	0.172	-0.106
Infiltration rate	**-0.238**	-0.142	-0.038
Clay%	**-0.233**	0.028	-0.223
Field Capacity	**-0.227**	0.123	-0.214
Salsola laricina	**-0.233**	-0.171	0.066
Artemisia sieberi	**-0.245**	0.061	-0.058
Class I	**-0.233**	-0.175	0.059
Class II	**-0.239**	-0.142	-0.008
Perennial forbs	**-0.231**	-0.195	0.005
Peganum harmala	**0.236**	-0.219	-0.202
Sand%	0.161	**-0.389**	0.158
Silt%	0.158	**0.398**	0.149
Perennial grass	-0.197	**-0.313**	0.117
Porosity	-0.222	**-0.231**	0.068
Organic Carbon(OC %)	-0.164	0.207	**-0.427**
Electrical Conductivity (EC)	0.154	-0.117	**0.501**
pH	-0.183	0.168	**0.398**
Class III	0.202	-0.215	**-0.275**
Noaea mucronata	0.202	-0.218	**-0.274**
Nitrogen (N)	-0.219	0.217	0.153

The bold and under lined data are the important in relevant axis.

Results of bi-plot diagram of the first and second components of PCA (Fig. 2) showed that bulk density was highest in ShirAli site and lowest in the excluded site (Ghorogh). In addition, there were significant differences for water infiltration rate among different grazing intensities. Infiltration rate decreased from enclosure site to heavily grazed area (ShirAli). Modification of soil physical properties by hoof action together with reduced vegetation cover often results in the increased bulk density and penetration resistance of soils (Wood and Blackburn, 1981). Higher bulk densities, lower water content and infiltration rate have been observed for different grazing animals in different grassland ecosystems because of increased animal trampling (Binkley *et al.*, 2003; Ilan *et al.*, 2008). Our results were therefore consistent with previous research. High grazing affects negatively plant species composition, spatial distribution and diversity of herbaceous layers. The situation further favours annual and unpalatable species than perennials, reduces the vegetation cover and results in the declines of range forage/fodder production (Tegegn *et al.*, 2011). According to results (Table 2 and Fig. 2), grazing intensity increased plant of class III such as *Peganum harmala* and decreased plant of class I and class II such as *Artemisia sieberi* and *Salsola laricina*. *Salsola laricina* is a palatable plant that is the best food resource for livestock along autumn and winter. Also, production and canopy cover of *Artemisia sieberi* were higher in enclosure and moderate grazing sites. Moreover, reduction of this species (*Artemisia sieberi*) in the Shirali site (continuous grazing in all the year with very high grazing) is probably amplified by the continuous removal of *Artemisia sieberi* by the communities for fuel and other purposes. Therefore, the effects of livestock grazing on many functional groups were less pronounced

in the areas grazed only during the dry season in contrast to the areas grazed continuously throughout the year. Grazing had a deleterious influence on ground cover. While moderate grazing caused a level of decline in ground cover that was beneficial to many species, heavy grazing may result in scalding and erosion (Calvert, 2001).
The vegetative plant cover in heavily grazed area is finally comprised of invader forb species such as *Peganum harmala, Noaea mucronata* and *Ceratocarpus* sp. that clearly indicates the destructive effect of heavy grazing on plant community and rangeland productive capacity. Based on the results, there was a significant difference in K in different areas. The highest amount of K was observed in Chaganeh and Shirali. Due to higher grazing intensity in Chaganeh and ShirAli rangelands compared to Nemati rangeland, the amount of soil potassium is higher. The increase of K values may have been related to livestock's positive effect on accumulation of K through trampling and their excreta. The results contrast with Javadi *et al.,* (2006). Aarons *et al.,* (2001) stated in a study about the role of cattle manure in soil fertility that soil K has almost been doubled under manure to 5 cm depth of soil. Increase of soil P level in Chaganeh and ShirAli might be related to excreta and litter deposition and more mobility of P on the soil surface due to livestock trampling. Haynes and William (1993) stated that more than 65% of P in the diet consumed by cows is returned to pasture. Soil P increase has been reported under manure (Haynes and William, 1993).

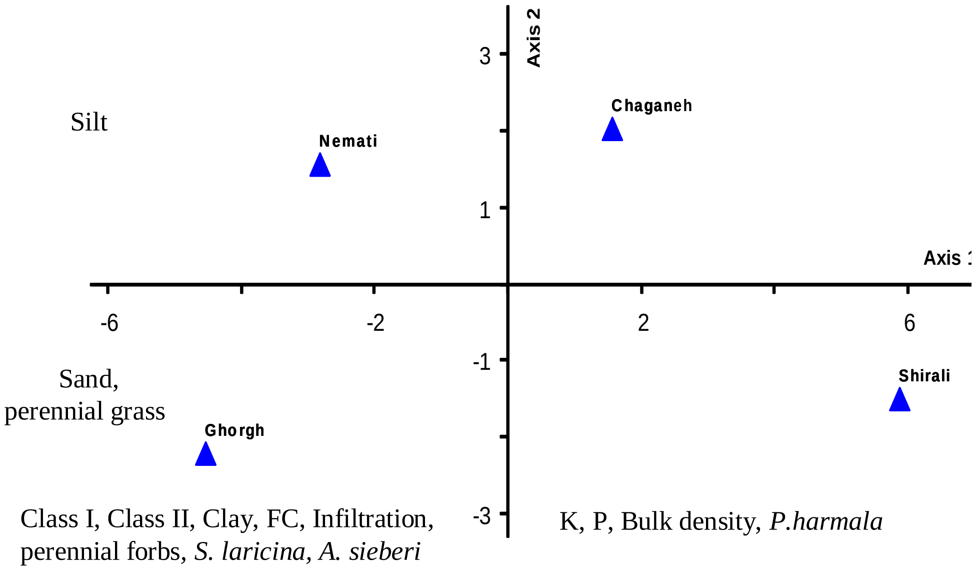

Fig. 2. Bi-plot diagram of the first and second components of PCA analysis on soil and vegetation properties for four sites (Ghorogh: exclosure (ungrazed), Nemati: moderate grazing intensity, Chaganeh: heavy grazing intensity and ShirAli: very heavy grazing intensity)

Conclusion

Good rangeland management practices, timely grazing and proper grazing intensity during the grazing period might be the key issues to maintain vegetation cover and reduce soil bulk density which leads to the increase in infiltration rate and decrease of sediment loss, runoff and soil erosion. Grazing management plans should include both economic and biological considerations. Therefore, they should focus upon possibilities that allow local population to use the land for rangeland by organizing a rotational grazing system and prevent grazing pressure by distributing the livestock more uniformly and ensuring that carrying capacity is not exceeded in order to maintain soil and vegetation conditions. More studies to better assess the time scale of exclusion are also needed to understand better the ecology of this fragile ecosystem.

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