DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 19-1 (2014) 57-63

Wildlife and Livestock Grazing Effects on Some Physical and Chemical Soil Properties (Case Study: Kalmand-Bahadoran Arid Rangelands of Yazd Province)

S. Hossein Jafari[a*], M.R. Tatian[a], R. Tamartash[a], A.A. Karimian[b]

[a] *Faculty of Agricultural Science and Natural Resources, University of Sari, Sari, Iran*
[b] *Yazd University, Yazd, Iran*

Received: 27 May 2013; Received in revised form: 6 November 2013; Accepted: 2 March 2014

Abstract

Owing to the importance and necessity of identifying soil properties in arid rangeland management, and the variable effects of different kinds of herbivores on soil, this study compares some of the physical and chemical properties of soil between two regions experiencing livestock and wildlife grazing in the desert rangelands of Kalmand-Bahadoran in Yazd province. The key areas in two regions experiencing livestock and wildlife grazing were selected, and soil samples were taken at depths of 0-30 cm using the systematic random sampling method. All samples were then transferred to the laboratory to determine the desired parameters. Finally, soil characteristics were compared between the two regions. The results indicate that physical properties of the soil such as clay and moisture percentage show no significant differences. Bulk density in the region of livestock grazing reveals a highly significant increase compared to the area under wildlife grazing ($P<0.01$). Calcium carbonate, acidity and electrical conductivity parameters also saw a significant increase from 18.33%, 8.47% and 1.46% in the region with livestock grazing to 14.91%, 8.36% and 1.35% on the wildlife grazing site respectively ($P<0.01$). In terms of organic matters there was no significant difference between the two study sites. Overall, changes in soil properties have occurred as a result of wildlife grazing from halophyte and shrub species and from less grazing pressure at the site.

Keywords: Desert; Livestock; Wildlife; Physical Chemical Properties; Soil; Yazd

1. Introduction

Rangelands serve as enormous natural resources to meet human needs, playing one of the main factors in sustainable development. Degradation of rangeland ecosystems occurs mainly due to grazing, the assessment of which is generally based on soil and vegetation conditions (Donkor *et al.*, 2001; Zhao *et al.*, 2007; Mohebby *et al.*, 2013). Soil is one of the most important factors affecting production potential (Fotouhi *et al.*, 2012) and utilization of rangelands, imbalance between capacity and numbers of grazing livestock can cause significant changes in soil characteristics (Holecheck *et al.*, 1995; Pei *et al.*, 2008; Kumbasli *et al.*, 2010). The presence of herbivores in a natural ecosystem can determine various properties including soil compaction, break-down and decrease in aggregate stability, reduction in the amount of available moisture, change in soil and vegetation type and finally the physical and chemical characteristics of the soil (Steffens *et al.*, 2008). Most changes, especially changes in a soil's physical properties, are a result of soil compaction or density increase caused by trampling (Chaichi *et al.*, 2003; McDowell *et al.*, 2004; Du Toit *et al.*, 2009; Azarnivand *et al.*, 2011). During the compaction process, soil

* Corresponding author. Tel.: +98 913 3561301,
Fax: +98 151 3822575.
E-mail address: samirahosseinjafari@yahoo.com

particles become closer together, undergoing a reduction in porosity and an increase in density (Sanadgol, 2002; Huang *et al.*, 2007; Afrah *et al.*, 2010). Another effect of grazing is a reduction in the amount of water penetration in the soil, thus decreasing its moisture content. Sanadgol (2006) found there to be little hydrological difference between various pastures under balanced and continuous grazing, but in arid and semi-arid rangelands there is no significant difference in the water permeability of the soil when under light, medium or no grazing. Owing to the fact that soil is more stable than vegetation and is usually affected after it, by preventing the development of this process in the early stages of degradation it can be hoped to restore vegetation easily with the lowest costs and over the shortest possible time (Moghaddam, 2009). Identifying and assessing the value and type of grazing effect will help scientific and systematic range management, which requires adequate knowledge (Jalilvand *et al.*, 2007; Cuevas *et al.*, 2012). Different results have been reported as to the effects of grazing on soil characteristics, which may be due to different climate, soil, vegetation, range management and animal types. Some studies suggest that a reduction in grazing intensity causes a significant decrease in bulk density and increases moisture content (Eteraf & Telvari, 2005; Yong-Zhong *et al.*, 2005; Moradi *et al.*, 2008). With increasing grazing intensity, acidity and calcium carbonate will increase, whilst the amount of organic matter and electrical conductivity will significantly decrease (Potter *et al.*, 2001; Moosavi *et al.*, 2001; Aghasi *et al.*, 2006; Pei *et al.*, 2008; Shifang *et al.*, 2008). McDowell *et al.* (2004) investigated the effects of deer grazing on soil quality in southern New Zealand. The results showed that bulk density in the paddock was 1.06 gr/cm^3 and 1.10 gr/cm^3, one day and six weeks after grazing, respectively. In general, it can be said that grazing causes changes in soil properties (Kohandel *et al.*, 2008). To manage a rangeland ecosystem, these changes should be identified to avoid unwanted and harmful conversions. Evaluating the effects of grazing is essential towards finding a way for effective management and the adoption of a strategy for stocking in rangelands. Owing to the importance of wildlife in range management and their role in desert rangelands, the problems of livestock grazing and the limited information about their grazing effects in desert areas, these studies are necessary in arid ecosystems. Because of the importance and necessity of identifying soil properties in arid rangeland management and due to the variable effects of different kinds of herbivores on soil, this study compares some of the physical and chemical properties of soil between two regions under livestock and wildlife grazing in the desert rangelands of Kalmand-Bahadoran in Yazd province.

2. Materials and Methods

2.1. Study site

The study site with an area of about 2550 hectares is located between 30 and 105 km southeast of Yazd, in the margin of Yazd-Kerman road at 31˚ 20' north latitude and 54˚ 30' east longitude. The average altitude is 1616 m above sea level. The study area was declared Kalmand-Bahadoran protected area in 1994. The soil in this area is predominantly composed of sand and loam. Maximum and minimum heights in the region are 3290 m and 1400 m respectively. The average annual precipitation is about 100 mm and the mean annual temperature is 33.17˚C. In livestock grazing areas, nearly 900 sheep and goat graze over four months per year (from 5th May to 5th October) while 240 deer graze continuously on the grazing site. The dominant species in this region is *Artemisia sieberi*. The other species include *Lactuca orientalis, Stachys inflata, Astragalus sp., Salaola sp., Noae mucronata* and *Scorzonera tortuosissima.*

2.2. Methodology

Firstly, the study area was determined using topographic maps and field investigation, where two regions were determined: one in the protected area under wildlife grazing (deer) and the other outside this area under livestock grazing (sheep and goat). The two regions are flat and their climatic and topographic conditions- slope, aspect and height- are the same (Consulting engineers of Iran, 2002; Alikhani & Ahmadi, 2012). Sampling was performed using the systematic random method. Depending on vegetation type and condition, ten random transects of 100m (Fakhimi Abarghoie *et al.*, 2011) and three plots of $2m^2$ were placed on each transect using the systematic method on each site (Eftekhari *et al.*, 2009; Fakhimi Abarghoie et al., 2011). Appropriate numbers of plots were calculated using the statistical method $N= t^2s^2/p^2x^2$ in which (N) is the number of samples required, (t) from t student table with the desired probability level (5%), (x) is the average primary sample, (p) error limit that usually is equal to +0.1 and -0.1, (s^2) is primary sample variance (Mesdaghi, 2003). Plot size was determined by minimal area method for each type (Mesdaghi, 2003). Soil samples (30 profiles) were taken at depths of 0-30 cm in each plot on each site (average depth of soil upper horizon). In the laboratory, bulk density (by the cylinder method) and soil texture (by the hydrometric method) were measured. Soil pH and electrical conductivity were determined using a pH meter and EC meter in saturated mud (Rhoads, 1982; Mclean, 1988). To measure organic matters, the Walkley-Black method was used (Nelson & Sommers, 1982). Moisture and calcium carbonate levels were determined by Oven and titration method respectively (Jafari Haghighi, 2003). The data were analysed by performing an independent sample t-test using *SPSS 16* Software.

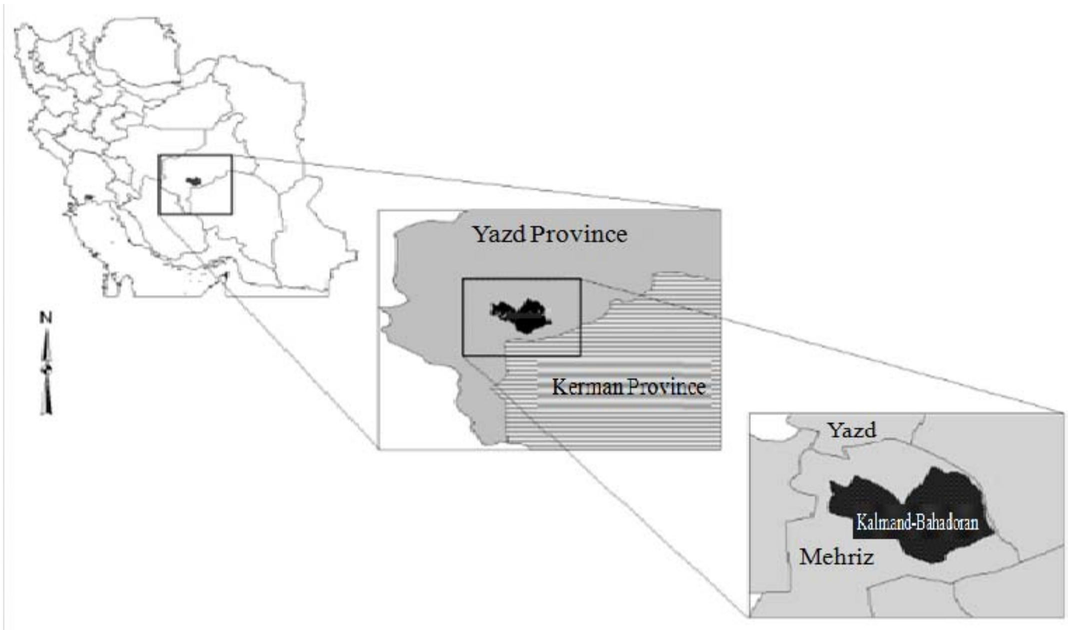

Fig. 1. Kalmand-Bahadoran protected area position, located in Yazd province, central part of Iran

3. Results

Table 1 shows significant difference between the two regions in terms of sand and silt percentage (P<0.01), with sand percentage demonstrating a significant increase in the region under deer grazing compared to the livestock grazing region, while silt percentage under livestock grazing has increased significantly. There is no significant difference between the two regions in terms of clay percentage.

Table 1. Comparing soil texture parameters including sand, silt and clay between two regions under wildlife and livestock grazing using independent sample t- test

Soil texture parameters (%)	Study site	Average	Sd	df	t	Significant
Sand	Wildlife	82.71	5.41	58	4.345	0.000**
	Livestock	77.90	2.74			
Silt	Wildlife	5.91	2.61	58	- 8.745	0.000**
	Livestock	10.90	1.71			
Clay	Wildlife	11.37	3.53	58	0.238	0.813ns
	Livestock	11.20				

(ns: No significant), (**P<0.01)

The results of comparing other physical parameters shows that there is no difference between the two regions in terms of moisture, but bulk density statistical analysis indicates a significant difference between the two regions, with soil under livestock grazing being higher than the wildlife area (P<0.01) (Table 2).

Table 2. Comparing soil physical parameters between two regions under wildlife and livestock grazing using independent sample t-test

Soil physical parameters (%)	Study site	Average	Sd	df	t	Significant
Moisture (%)	Wildlife	0.98	0.32	58	- 0.749	0.457[ns]
	Livestock	1.04	0.31			
Bulk density	Wildlife	0.75	0.13	58	6.351-	0.000[**]
	Livestock	0.98	0.15			

([ns]: No significant), ([**]P<0.01)

According to Table 3, the results of comparing soil chemical parameters indicate that there are significant differences between calcium carbonate, acidity and electrical conductivity in the two regions and all three parameters under livestock grazing show a significant increase compared to the wildlife area. However, there is no significant difference between the two regions in terms of organic matter.

Table 3. Comparing soil chemical parameters between two regions under wildlife and livestock grazing using independent sample t-test

Soil chemical parameters (%)	Study site	Average	Sd	df	t	Significant
Calcium carbonate	Wildlife	14.91	1.77	58	- 8.561	0.000[**]
	Livestock	18.33	1.28			
Acidity	Wildlife	8.36	0.091	58	- 5.030	0.000[**]
	Livestock	8.47	0.087			
Electrical conductivity	Wildlife	1.35	11.59	58	- 3.105	0.003[**]
	Livestock	1.46	17.23			
Organic matters	Wildlife	0.28	0.15	58	1.628	0.109[ns]
	Livestock	0.22	0.14			

([ns]: No significant), ([**]P<0.01)

4. Discussion and Conclusions

These results indicate a change in some physical soil properties such as sand and silt in two regions under wildlife and livestock grazing, with an increase in the amount of sand and a decrease in silt percentage under wildlife grazing. This confirms that deer grazing has no negative effect on these properties. Wildlife grazing areas nearby Baghe Bidmeshk and Kermanshahan mountains are susceptible to erosion, causing sand transmission to this region via intensive winds. This can change soil texture, therefore being the reason for increasing sand percentage on the deer grazing site. Wang and Gong (1998), Ajorlou (2007), Du Toit *et al.* (2009) and Cournane *et al.* (2011) have also explained the effect of surrounding areas on sand and stone transition to their studied areas.

Higher livestock concentrations and traffic have caused a bulk density increase in livestock grazing sites, which Du Toit *et al.* (2009) demonstrated through their research. Owing to decreasing bulk density, higher porosity and lower water holding capacity on the deer grazing site, moisture has decreased in this area. Some researchers have also demonstrated that increasing bulk density has led to moisture reduction (Klein *et al.*, 2003; Santos, 2003; Mahmoodi & Hakimian, 2007; Azmoodeh *et al.*, 2010). Increasing soil acidity in the livestock grazing area confirms that livestock pressure is higher than that of wildlife, so that livestock along with soil layer degradation brings the lowest carbonate layer closer to the surface and ultimately causes a significant increase in the acidity and calcium carbonate levels of the soil in this area (Dormaar, 1998; Bagheri *et al.*, 2009).

In terms of salinity, a significant reduction in electrical conductivity under the wildlife grazing area is possibly due to deer grazing from halophyte species, since livestock do not use halophyte species. This results in the returning of their matters to the soil and can lead to increasing soil salinity (Ghorbanian & Jafari, 2007; Zarekia *et al.*, 2012).

The results indicate that the organic matter content of soil in the two regions was low. Schuman *et al.* (1999) has stated that non-breaking and non-mixing plant residues with the soil are the reason for increasing organic matters. Vegetation plays an important role in the amount of organic matter because of its type and density. Soils under plant cover with a lot of roots have more organic matter (Imhoff, 2000; Javadi *et al.*, 2005). Therefore, according to desert conditions, the low vegetation and distance between plants, and the low root content in soil, can lead to a reduction in organic matter. Furthermore, the results show a reduction of organic matter under a livestock grazing area. This issue can be caused by high levels of livestock grazing on all species except halophytes, a lower percentage of cover, plant biomass and finally lower returning organic matter to the soil. Other research has shown that any reduction in organic matter to the soil results in disorders in degrading microorganisms' activity and less breaking down of organic matter (Kumbasli *et al.*, 2004; Jalilvand *et al.*, 2007; Haidarian Aghakhani *et al.*, 2010; Xie & Witting, 2010). According to the results, it seems that soil changes are more related to livestock grazing pressure than they are to deer grazing.

References

Afrah, H., H. Barani, A. Bahremand, V. Sheikh, 2010. Comparison of soil physical properties in micro terraces and inters micro terraces on rangelands (case study: Baba Shamlak Ranch). Journal of Water and Soil Conservation, 17(2); 141- 153.

Aghasi, M.J., M.A. Bahmaniar, M. Akbarzadeh, 2006. Comparison of the effects of exclusion and water spreading on vegetation and soil parameters in Kyasar rangelands, Mazandaran province. Journal of Agric. Sci. Natur. Resour., 13(4); 73-87.

Alikhani, A., M.R. Ahmadi, 2012. range management project of Sarve, Ernan, Kamalabad summer Rangeland. Department of Natural Resources and Watershed in Yazd province, 40 p.

Azarnivand, H., A. Farajollahi, E. Bandak, H. Pouzesh, 2011. Assessment of the effects of overgrazing on the soil physical characteristic and vegetation cover changes in rangelands of Hosainabad in Kurdistan province, Iran. Journal of Rangeland Science, 1(2); 95- 102.

Azmoodeh, A., A. Kavian, K. Soleimani, Gh. Vahabzadeh, 2010. Comparing runoff and soil erosion in forest, dry farming and garden land uses soils using rainfall simulator. Journal of Water and Soil, 24(3); 490- 500.

Bagheri, E., M. Mesdaghi, M. Amirkhani, 2008. Comparison of vegetation composition under exclosure, gazelle and sheep grazing in Golestan National Park and vicinities. Pajouhesh & Sazandegi, 80; 83- 93.

Bagheri, R., M. Mohseni Saravi, M.R. Chaichi, 2009. Effect of grazing intensity on some soil chemical properties in a semi arid region (case study: Khabr National Park and near rangelands). Rangeland, 3(3); 398- 412.

Chaichi, M.R., M. Mohseni Saravi, A. Malekian, 2003. Trampling effects of livestock grazing on soil physical properties and range vegetation cover. Iranian Journal of Natural Resources, 56(4); 491- 508.

Consulting engineers of Iran, 2002. Management project of Kalmand-Bahadoran protected area. 14, (vegetation section) 180 p.

Cournane, F.C., R. Mc Dowell, R. Littlejohn, L. Condron, 2011. Effects of cattle, sheep and deer grazing on soil physical quality and losses of hosphorus and suspended sediment losses in surface runoff, Agriculture. Ecosystems and Environment, 140 (2); 264- 272.

Cuevas, M. F., L. Mastrantonio, R.A. Ojeda, F.M. Jaksic, 2012. Effect of Wild boar disturbance on vegetation and soil properties in the Monte Desert, Argentina. Mammalian Biology, 77; 299- 306.

Donkor, N.T., J.V. Gedir, R.J. Hudson, E.W. Bork, D.S. Chanasyk, M.A. Naeth, 2001. Impacts of grazing systems on soil compaction and pasture production in Alberta. Canadian Journal of soil science, 82; 1-8.

Dormaar, J.F., S. Smoliak, W.D. Willms, 1998. Vegetation and soil responses to short duration grazing on Fescue grasslands. Journal of Range Management, 42 (3); 252- 256.

Du Toit, G. van N., H.A. Snyman, P.J. Malan, 2009. Physical impact of grazing by sheep on soil parameters in the Nama Karoo subshrub/grass rangeland of South Africa. Journal of Arid Environments, 73; 804- 810.

Eftekhari, A., M. Farahpour, H. Arzani, J. Abdollahi, 2009. Investigation and comparison of species under livestock (sheep & goat) and wildlife (deer) grazing in steppic rangelands of Poshtkooh in Yazd province. Agriculture and Natural Resources Science and Technology, 47; 367- 379.

Eteraf, H., A. Tevari, 2005. Effects of animal grazing on some physical characteristics of loose soil in Maravetapeh rangelands, Golestan, Iran. Pajouhesh & Sazandegi, 66; 8- 13.

Fakhimi Abarghoie, E., M. Mesdaghi, G.A. Dianati Tilki, 2011. The variation of vegetation factors along the grazing gradient in steppic rangelands of Nodushan, Yazd Province, Iran. Iranian Journal of Range and Desert Research, 18 (2); 219-230.

Fotouhi, F., H.R. Azimzadeh, A. Talebi, M.R. Ekhtesasi, 2012. Analyzing the changes of soil erodibility index (k) in the soils of arid regions and the effective factors in central Iran (case study: Yazd-Ardakan plain). DESERT, 17; 65- 75.

Ghorbanian, D., M. Jafari, 2007. Study of soil and plant characteristics interaction in Salsola rigida in desert lands. Iranian Journal of Range and Desert Research, 14 (1); 1-7.

Haidarian Aghakhani, M., A.A. Naghipour Borj, M. Nasri, 2010. The effects of exclosure on vegetation and soil chemical properties in Sisab rangelands, Bojnord, Iran. Journal of Renewable Natural Resources, 1 (2);14- 27.

Holechek, J., R.D. Pieper, C.H. Herbel, 1995. Range management; Principales and practices. 2th ed., a Simon and Schster Company upper Saddle River, New Jersey.

Huang, D., K. Wang, W.L. Wu, 2007. Dynamics of soil physical and chemical properties and vegetation succession characteristics during grassland desertification under sheep grazing in an agro-pastoral transition zone in Northern China. Journal of Arid Environ., 70; 120- 136.

Imhoff, S., A.P. da Silva, C.A. Tormena, 2000. Spatial heterogeneity of soil properties in areas under elephant-grass short-duration grazing system. Plant and Soil, 219 (1-2); 161- 168.

Jafari Haghighi M., 2003. Soil analysis, sampling and important physical and chemical analysis method with emphasis on theory and application basics, Nedaye zoha press, 240 p.

Jalilvand, H., R. Tamartash, H. Heydarpour, 2007. Grazing impact on vegetation and some soil chemical properties in Kojour Rangelands, Noushahr, Iran. Rangeland, 1; 53- 66.

Javadi, S.A., M. Jafari, H. Azarnivand, S.J. Alavi, 2005. An investigation of the grazing intensity effects on variations of soil organic matter and nitrogen in Lar rangelands. Iranian Journal of Natural Resources, 58 (3); 711- 718.

Klein, C.A.M., J.J. Drewry, J.W. Nagels, M. Scarsbrook, R. Collins, R.W. Mc Dowell, R. Muirhead, 2003. Environmental impacts of intensive deer farming in New Zealand - a review. The Nutrition and Management of Deer on Grazing Systems, 79-88.

Kohandel, A., H. Arzani, A. Henth, 2008. The effects of artificial livestock trampling on germination and growth of *Stipa barbata*. DESERT, 13; 25- 29.

Kumbasli, M., E. Makineci, M. Cakir, 2010. Long term effects of red deer (Cervus elaphus) grazing on siol in a breeding area. Journal of Environmental Biology, 31; 185- 188.

Mahmoodi, Sh., M. Hakimian, (Henry D. Foth), 2007. Fundamentals of soil science, University of Tehran press, Tehran.

Mc Dowell, R.W., J.J. Drewry, R.J. Paton, 2004. Effects of deer grazing and fence- line pacing on water and soil quality. Journal of Soil use and management, 20; 302- 307.

Mclean, E.O., 1988. Soil pH and lime requirement. In: page, AL, editor. Methods of Soil an analysis Part, American Society of Agronomy, vol.2. Soil Science Society of America, Madison, Wis.: p. 199- 224.

Mesdaghi, M., 2003. Rangemanagement in Iran, Razavi press, Mashhad.

Moghadam, M.H., 2009. range and range management. 6th ed., University of Tehran press, Tehran.

Mohebby, A., M. Jafari, A. Tavili, S.A. Javadi, E. Zandi Esfahan, M. Ramezani, 2013. Effect of livestock grazing on growth characteristics of Atriplex Canescens. DESERT, 17; 299- 303.

Moosavi, S.M., 2001. effect of grazing on vegetation and soil changes in semi-steppe rangelands of Rezaabad in Semnan province. The second national conference articles of range and range management in Iran, Iran range management society.

Moradi, H.R., S.K. Mirnia, M. Faragzadeh, 2008. Effect of grazing intensities on the soil physical properties and vegetation cover of Charandoo summer rangelands in Kurdistan province. Iranian Journal of Range and Desert research, 15 (3); 369- 378.

Nelson, D.W., L.E. Sommers, 1982. Total carbon, organic carbon, and organic matter. In: Page, AL, editor. Methods of Soil Analysis. Part2. Chemical and Microbiological Properties, second ed. Agronomy Monographs, 9. ASA-SSA, Madison, WI; p. 539-579.

Pei, Sh., H. Fu, Ch. Wan, 2008. Changes in soil properties and vegetation following exclosure and grazing in degraded Alxa desert steppe of Inner Mongolia, China. Agriculture Ecosystems & Environment, 124; 33-39.

Potter, K.N., J.A. Daniel, W. Altom, H.A. Torbert, 2001. Stocking rate effect on soil carbon and nitrogen in degraded soils. Soil and Water Conservation, Vol. 56 (3); 233- 236.

Rhoads, J.D., 1982. Soluble salts. In: Page, AL, editor. Methods of Soil Analysis, American Society of Agronomy. Soil Science Society of America, Madison, Wis.; p. 167- 179.

Sanadgol, A., M. Moghadam, M. Jafari, 2002. Effects of short-term grazing on some soil physical and chemical characteristics in a Bromus tomentellus pasture. Iranian Journal of Natural Resources, 55 (4); 581- 597.

Sanadgol, A., 2006. Effects of grazing systems and grazing intensities on soil moisture content in Bromus tomentellus pasture. Pajouhesh & Sazandegi, 73; 49-54.

Santos, F.L., J.L. Reis, O.C. Martins, N.L. Castanheria, R.P. Serralherio, 2003. Comparative assessment of infiltration, runoff and erosion of sprinkler irrigation soils. Biosystems Engineering, 86 (3); 355-364.

Schuman, G.E., J.D. Reeder, J.T. Manley, R.H. Hart, A. Manley, 1999. Impact of grazing management on the carbon and nitrogen balance of a mixed-grass rangeland. Ecological Applications, 9; 65- 71.

Shifang, P., F. Hua, W. Changgui, 2008. Changes in soil properties and vegetation following exclosure and grazing in degraded Alxa desert steppe of Inner Mongolia, China. Agriculture, Ecosystems and Environment, 124; 33- 39.

Steffens, M., A. Kolbl, K.U. Totsche, I. Kogel-Knabner, 2008. Grazing effects on soil chemical and physical properties in a semiarid steppe of Inner Mongolia (P. R. China). Geoderma, 143; 63- 72.

Wang, X., Z., Gong, 1998. Assessment and analysis of soil quality changes after eleven years of reclamation in subtropical China. Geoderma, 81; 339-355.

Xie, Y., R. Wittig, 2004. The impact of grazing intensity on soil characteristics of Stipa grandis and Stipa bungeana steppe in northern China (autonomous region of Ningxia). Acta Oecol, 25; 197- 204.

Yong- Zhong, S., L. Yu- Lin, C. Jian- Yuan, Zh. Wen-Zhi, 2005. Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. Catena, 59; 267- 278.

Zarekia, S., M. Jafari, H. Arzani, S.A. Javadi, A.A. Jafari, 2012. Grazing effects on some of the physical and chemical properties of soil. World Applied Sciences Journal, 20 (2); 205-212.

Zhao, Y., S. Peth, J. Krummelbein, R. Horn, Z. Wang, M. Steffens, C. Hoffmann, X. Peng, 2007. Spatial variability of soil properties affected by grazing intensity in Inner Mongolia grassland. Ecol. Model., 205; 241- 254.