DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 25-1 (2020) 7-13

Monthly variation of production of key range species in central arid rangeland, Case study: Saveh-Markazi Province, Iran

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Received: 16 June 2019; Received in revised form: 17 September 2019; Accepted: 24 September 2019

Abstract

Forage production of rangelands differs during different times of grazing season and in the same month of different years. In range management projects, grazing capacity calculated once during the grazing season, which coincides with the maximum production of rangeland species. This may cause more livestock entry into the rangeland during the grazing season, leading to more degradation. Therefore, it is necessary to measure forage production during the months of grazing season over a few years, based on which the long-term grazing capacity of key range species could be estimated. Production variations of the key species, namely *Artemisia sieberi, Salsola laricina,* and *Stipa hohenackeriana* were investigated in Khoshkerood-e-Saveh site in growth and grazing season over the course of three years. For this purpose, the production of each species measured in a one-hectare exclosure with one month intervals until the growth dormancy. After air-drying, forage production was analyzed by SAS software. Based on the results, due to the high variability of monthly and annual precipitation in the region, forage production of key range species had significant differences at P $\leq$5% level. The maximum and minimum mean production (543 and 388 kg/ha) belonged to 2009 and 2008, respectively. According to the production fluctuation in different years, it is recommended that range management plans account for the long-term average of good production.

Keywords: Steppic rangelands; Key range species; Production; Grazing capacity; Region

1. Introduction

Area of rangeland is an indicator of ecosystem diversity at a national scale (Mitchell, 2000). Rangelands are the most important part of the renewable resources owing to the lower cost of their forage production in comparison with irrigated farming. The rangeland area of Iran is currently around 82 million ha, and the production of dry matter as fodder is estimated at about 11.7 million tons (Arzani, 2009). Forage production in rangelands differs at different times of grazing season and in the same month of different years.

Climate change is expected to have a range of effects that will potentially alter rangeland ecosystems (Polley *et al*., 2013). Simulations have indicated that even a relatively small percentage of change in rainfall has impacts that are more significant on forage production for grazing species (McKeon *et al*., 2009). Accordingly, the estimated data related to production in a specific year are not sufficient for long-term planning in rangeland (Arzani, 1994). Annual precipitation fluctuations in steppic rangelands are high; however, their distribution throughout the year is very erratic (Arzani, 1994), and water stress associated with drought increases mortality in species in spite of their different stress tolerance (Plaut *et al*., 2012). Such climatic characteristics severely affect forage production in these areas during different years. Drought and wet years have various effects on the production of species (Najafi Tireh

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Shabankareh *et al*., 2014), and deeper root systems are resistant to heat and drought (Liu *et al*., 2018). Therefore, given the variations in the production of species in different periods of grazing and different years, grazing capacity should be determined based on the production of each grazing season (Arzani, 1994). A modeling exercise found that increased annual precipitation variability and temperature in the Tibetan Plateau reduced the productivity of grasslands (Ye *et al*., 2013).

In a study on Alamut mountainous rangelands of Ghazvin, Rashvand *et al*., (2014) assessedthe forage production sustainability of several rangeland species and reported that *Artemisia aucheri* and *Cousinia esfandiari* had a sustainable production. Many studies have been performed concerning the production and role of precipitation and moisture for plant production (Fakhimi *et al*., 2014; Zarekia *et al*., 2012; Yang *et al*., 2008). These studies have underscored the role of precipitation and moisture content in increasing forage production.

Ahmadi *et al*., (2013) investigated the production trend of plant species in Urmia-Qarabagh rangelands; they showed that in most species, the highest amount of forage production occurred in the year with the most rainfall. Therefore, during the six months of April to September, the highest amount of production in all years occurred in May while the lowest amount belonged to September, followed by April. Without determining the production characteristics of plant species, it is not possible to plan and manage rangeland and livestock.

The present research was conducted to examine the production of important species belonging to the steppic rangelands of Saveh, central Iran. By so doing, it is possible to revise the grazing management plan of rangelands with similar plant species and finally provide useful information on the dynamics of rangeland and livestock productions.

2. Materials and Methods

2.1. Study areas

The studied steppic rangeland is located 60 km northeast of Saveh, Markazi province between longitudes of 50° 35' 49" to 50° 49' 11" and latitudes of 35°23'46" to 35° 30' 55". (Fig. 1)

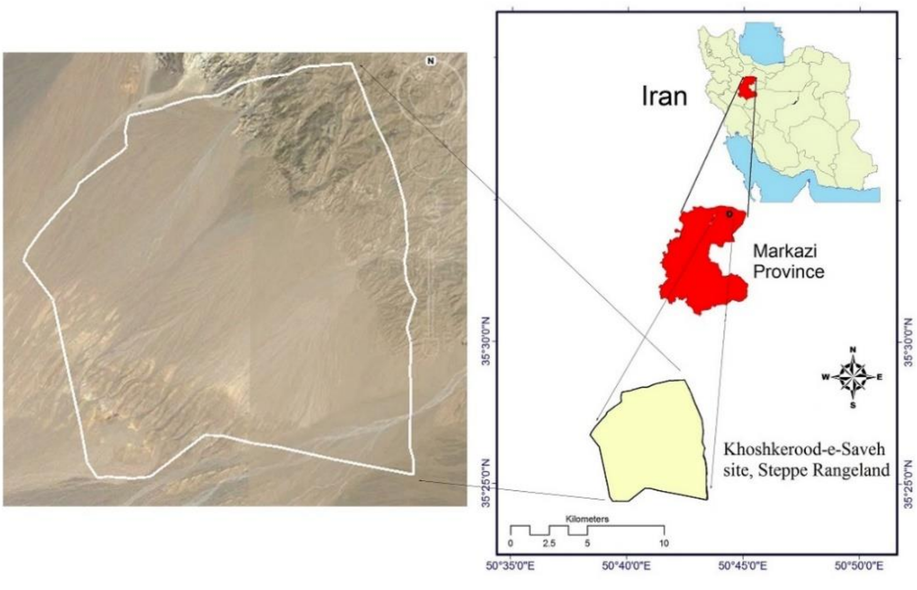

Fig. 1. Study area in Markazi Province, Iran

Based on the long-term data of Saveh synoptic station, the mean annual temperature and precipitation of the study area are 19°C and 200 mm, and the mean monthly temperature ranges from 4.5°C in January to 32.6 °C in July, with 51–89% occurring in the growing season (March – June). The area comprises both steep and flat terrains. The region has an altitude of 1325 m a.s.l with sandy clay loam of soil texture. Khoshkehrood Rangeland considered as a summer rangeland. The dominant vegetation type is *Artemisia sieberi –Salsola laricina*. The main species are *Stipa hohenackeriana*, *Poa sinaica*, *Scariola orientalis*, *Noaea mucronata*, *Cousinia cylindraceae*, *Dendrostellera lessertii*, *Acanthophyllum microcephalum*, *Andrachne fruticulosa*, *Achillea tenuifolia*, *Ajuga sp.*, *Boissiera squarrosa*, *Bromus tectorum*, *Carex stenophylla*, *Ceratocarpus arenarius, and Dianthus sp.*

Table 1. Monthly and annual variations in precipitation (mm) during the project period and long-term periods (1992-2010)

Month	2008	2009	2010	Long-term
December	15.0	6.0	11.6	33.4
January	23.2	21.0	13.2	18.1
February	0.7	1.5	20.4	21.1
March	6.4	70.7	25.3	30.8
April	2.4	35.2	44.5	20.5
May	5.4	0.8	0.0	1.8
June	0.0	0.0	0.0	0.8
July	0.0	0.0	0.0	0.1
August	0.0	3.2	0.0	0.6
September	0.5	0.0	1.9	2.5
October	4.7	45.0	17.3	28.9
November	41.7	39.5	28.7	31.2
Average	100.0	222.9	162.9	190.2

2.2. Methods

The monthly forage production of *Artemisia sieberi, Salsola laricina,* and *Stipa hohenackeriana,* the key range species (Fig. 2) in the region, was calculated from the beginning of the growing season for three years, inside a one-hectare enclosure area, with one-month intervals until growth dormancy. Five plants were selected from each species and monthly marked in the enclosure area. In systematic random sampling, the coverage and density of all species were estimated within the enclosed region in order to specify the mean plant size.

Each month, for each species, the harvested forage was placed in separate bags and after drying, the dry-matter weight was obtained. The amount of forage production, after air-drying, was analyzed by SAS software. Total production was calculated at specified intervals using the production average and species density in rangeland.

Fig. 2. *Artemisia sieberi, Salsola laricina,* and *Stipa hohenackeriana* species in Khoshkehrood Rangeland (left to right)

3. Results

According to Duncan's multiple-range test (Table 2), *Artemisia sieberi*, *Salsola laricina*, and *Stipa hohenackeriana* had significantly different forge productions over the studied years ($p \leq 0.05$). The highest and the lowest amount of total forage production in these three species was observed in 2009 (rainfall: 220 mm) and 2008 (rainfall: 100 mm), respectively, indicating a 14% increase.

Table 2. Mean comparison of the annual production of key species

Year	forage production (kg/ha)
2008	388±48.5 b
2009	543.4±72.9 a
2010	478.2 ±62.1 ab

Values with the same letters were not significantly different ($P<0.05$)

Table 3. Mean comparison of the monthly production of key species

Month	Average forage production (kg/ha)
March	36.4±4.5 b
April	47.8±5.6 ab
May	50.1±6.4 a
June	22.1±4.4 c

Values with the same letters were not significantly different ($P<0.05$)

According to the results (Table 3), all three species had statistically different productions in the months of the growing season. The average production in May was the highest but did not significantly differ from April, and June had the lowest production. Table 5 shows the relative monthly production of *S. laricina* based on the total amount of rangeland production. On average, more forage was produced in April (30.3%) whereas in June, the share of the species was approximately 15.1%. However, in different years, these proportions slightly differed. In 2008, around 6% of the forage was produced in October, which was not observed in the following years. Based on the average of three years, the share of this species in the total forage production of rangeland was about 50% (Table 4).

Table 4. Monthly relative production of *S. laricina* in different months and its share of total rangeland production

Years	Monthly relative production (%)												Relative production
	March	April	May	June	July	August	September	October	November	December	January	February	
2008	22.1	32.4	36.0	3.7	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	53.4
2009	22.1	3.6	37.8	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.9
2010	36.1	42.7	17.1	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.7
Average	26.7	26.2	30.3	15.1	0.0	0.0	0.0	1.93	0.0	0.0	0.0	0.0	50.66

Table 6 shows the relative monthly production of *A. sieberi* based on the total amount of rangeland production. On average, more forage was produced in April (37.4%) while in June; the share of the species was 11.9%. However, these proportions slightly differed over different years. According to the average of three years, the share of this species in the total forage production of rangeland was about 23%.

Table 5. Monthly relative production of *A. sieberi* in different months and its share of total rangeland production

Years	Monthly relative production (%)												Relative production
	March	April	May	June	July	August	September	October	November	December	January	February	
2008	28.6	36.0	32.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
2009	12.1	25.2	33.0	29.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
2010	21.8	51.1	24.1	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.3
Average	20.8	37.4	29.8	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.8

The relative monthly production of *S. hohenackeriana* based on the total amount of rangeland production showed that on average, more forage was produced in May (39.8%) while in June; the production share of the species was about 1.8%. The average of three years showed that the share of this species in the total forage production of rangeland was about 17%.

Table 6. Monthly relative production of *S. hohenackeriana* in different months and its share of total rangeland production

Years	Monthly relative production (%)												Relative production
	March	April	May	June	July	August	September	October	November	December	January	February	
2008	26.5	23.3	50.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3
2009	7.6	36.2	40.9	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0
2010	24.1	38.2	28.5	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.2
Average	19.4	32.5	39.8	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8

The interaction effect of different species production in the months and years of the study revealed that the highest amount of production belonged to *S. laricina* with 114 kg/ ha in April 2010 and 105 and 106 kg/ha in May and June 2009, respectively. The least forage belonged to *S. hohenackeriana* and *A. sieberi* in May 2008 (Fig. 3).

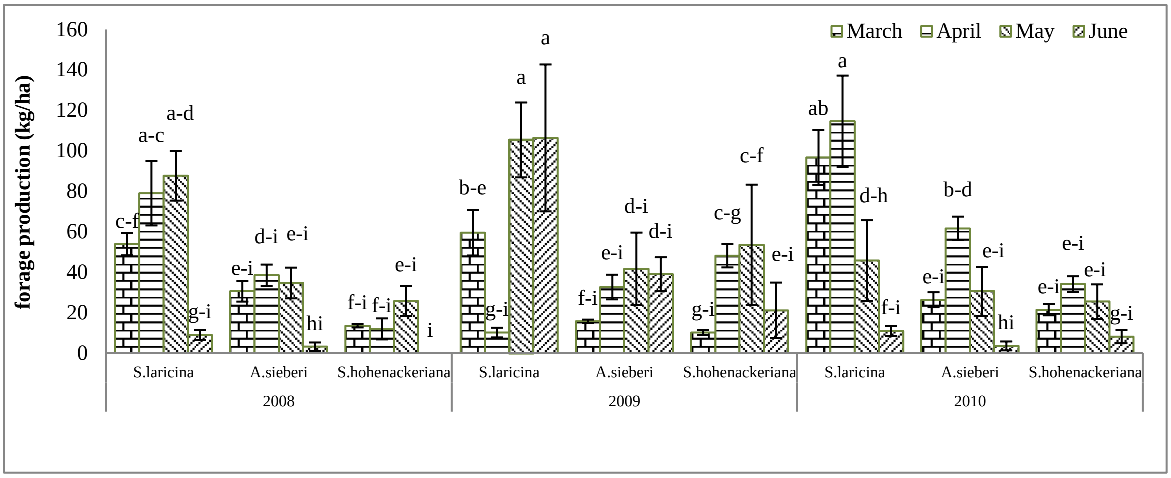

Fig. 3. Changes in the production (kg/ha) of species in different months and years

4. Discussion

Artemisia sieberi, *Salsola laricina*, and *Stipa hohenackeriana* have a high proportion of forage production in the winter rangelands of Khoshkehrood, Saveh. These species account for about 88% of the total vegetation cover in the region and around 90% of the forage. The results showed that the production of the species varied in different months and years (2008 and 2010). Due to winter rainfall, the highest production occurred in April and May (vegetative stage), and the amount of production decreased with the reduction in the rainfall in June (end of the vegetative stage). However, in 2010, the highest production occurred in April, which decreased over time towards June. According to Table 1, the rainfall in the winter months, especially March 2010, caused the highest production in April whereas the low rainfall in March and the previous months in the years 2008 and 2009 did not increase the plant production in April. Instead, the increased rainfall in the spring augmented the production in May. With the increase in heat and reduction in rainfall, minimum production levels occurred in June over different years. Thus, in addition to rainfall and annual and monthly temperatures, plant production in the area is influenced by the distribution of rainfall in the months of the growing season. In growing seasons with suitable amounts of rainfall and distribution, there is a significant increase in forage production. According to many researchers, including Ahmadi *et al*. (2013), Chaplin-Kramer and George (2013), and Densmore-McCulloch *et al*. (2016), rainfall in the proper season and growth time of plant species significantly increases production. The most important climatic indices in the forage production of shrub plants in the rangelands of the steppe region of Aktarabad, Saveh were analyzed over the course of eight years (1998-2005); among the important climatic indices, rainfall during the growing season was the most effective and had a significant positive correlation with forage production (Ehsani *et al*., 2008; Li *et al*., 2016). Grasses are more severely affected by this condition as was shown by Rahmani *et al*., (2014) who examined the forage production of *Agropyron desertorum* under the influence of average annual rainfall. They suggested that the correlation between decreasing or increasing forage production with the decrease and increase in average annual rainfall was more than 88%. The total forage production was different in the studied years of the current research. The data showed that the indicator species of the region in 2008, whose rainfall was less than 100 mm, produced 30% less forage compared to 2009 with a rainfall of approximately 222 mm. Wesche (2005) has also reported that the changes in vegetation cover in arid areas are due to rainfall. However, the comparison of Tables 4 to 6 shows that the fluctuation of species production varied over different years, with shrub species such as *Salsola laricina* and *Artemisia sieberi* slightly fluctuating in 2008 (dry year) and 2009 (wet year). In addition, these species had a similar share of production relative to the total rangeland production in different years; however, compared with *Stipa hohenackeriana*, the production of this species was observed to be strongly influenced by rainfall. In this regard, the share of this species relative to the total rangeland production in a dry year, 2008 (11%), was much less than its share of the total rangeland production in a wet year, 2009 (22%). Researchers have reported that rangeland forage production is affected by many factors including the total annual precipitation and its distribution

and these effects vary in different species (Hobbs *et al*., 2007; Robinson *et al*., 2013).
Generally, the current study showed that the production period and the amount of forage production had monthly and annual changes, which must be due to the changes in the amount of rainfall, particularly annual and monthly rainfall distribution. The results of this study are in agreement with those reported by Moghaddam (1999) and Akbarzadeh (2005). Also similar to the present research, Sharrow (2007) reported that forage production changed with seasonal fluctuations, and Arzani (1994) showed the effects of climate change on the annual forage production of plant species.

Increased precipitation variability significantly reduced ecosystem primary production. Dominant plant-functional types showed opposite responses: perennial-grass productivity decreased by 81% while shrub productivity increased by 67%. This pattern can be explained by the different nonlinear responses to precipitation. Grass productivity presented a saturating response to precipitation where dry years had more negative effects than wet years had positive ones. On the contrary, shrubs showed increased response to precipitation, which augmented the average productivity with the rise in precipitation variability (Gherardia and Sala, 2015).

5. Conclusion

According to the results, grasses are influenced by annual rainfall more than the shrubs, which should be considered in the long-term planning and calculation of grazing capacity. Given the severe fluctuations in grass production in rangelands, it is noteworthy that a single measurement of rangeland production could not be used to determine the long-term grazing capacity. On the other hand, due to the decreasing trend of forage production in the last months of the grazing season/growth season (May and June) and prevention of livestock grazing, it is necessary that the livestock leave the rangelands sooner and fed by hand until the next migration.

Acknowledgments

It is with immense gratitude that we acknowledge the support and help of Forests, Rangelands, and Watershed Management Organization and Research Institute of Forests and Rangelands.

References

Ahmadi, A., M. Akbarzadeh, H. Yeganeh, M. Bakhashandeh, E. Ahmadi, 2013. Investigation on changes in consumption and production of rangeland species in Gharebagh rangelands of Urmia. Iranian Journal of Range and Desert Research, 20; 613-623.

Akbarzadeh, M., 2005. Investigation on vegetation changes in and out of the enclosure, in Roode shoor area, Journal of Range and Desert Research, 12; 167-188.

Arzani, H., 1994. Some aspects of estimating short and long term rangeland carrying capacity in the Western Division of New South Wales. PhD Thesis, University of New South Wales. Australia.

Arzani, H., 2009. Textbook of Rangeland measurement procedures analysis, Tehran University, Faculty of Natural resources, 47p.

Chaplin-Kramer, R., MR. George, 2013. Effects of Climate Change on Range Forage Production in the San Francisco Bay Area. PLoS ONE 8: e57723. https://doi.org/10.1371/journal.pone.0057723

Densmore-McCulloch, JA., DL. Thompson, LH. Fraser, 2016. Short-Term Effects of Changing Precipitation Patterns on Shrub-Steppe Grasslands: Seasonal Watering Is More Important than Frequency of Watering Events. PLoS ONE, 11; e0168663. https://doi.org/10.1371/journal.pone.0168663

Ehsani, A., H. Arzani, M. Farahpour, H. Ahmadi, M. Jafari, A. Jalili, H.R. Mirdavoudi, H.R. Abasi, M.S. Azimi, 2008. The effect of climatic conditions on range forage production in steppe rangelands, Akhtarabad of Saveh, Iranian journal of Range and Desert Research, 14; 249-260.

Fakhimi, H., H. Arzani, A. Javadi, M. Jafari, 2014. Impact of climatic factors on forage production in Ali Abad Rangeland, Iran Journal of Biodiversity and Environmental Sciences (JBES), 4; 411-420.

Gherardia, L.A., O.E. Sala, 2015. Enhanced precipitation variability decreases grass- and increases shrub-productivity. PNAS. 112; 12735-12740. https://doi.org/10.1073/pnas.1506433112

Galt, D., F. Molinar, J. Navarro, J. Joseph, J. Holechek, 2000. Grazing capacity and stocking rate. Rangelands, 22; 7–11.

Hobbs, R.J., S. Yates, H.A. Mooney, 2007. Long-term data reveal complex dynamics in grassland in relation to climate and disturbance. Ecological Monographs, 77; 545–68. https://doi.org/10.1890/06-1530.1

Li, H., F. Zhang, Y. Li, X. Zhao, G. Cao, 2016. Thirty-year variations of above-ground net primary production and precipitation-use efficiency of an alpine meadow in the north-eastern Qinghai-Tibetan Plateau. Grass and forage science, 71; 208-218. https://doi.org/10.1111/gfs.12165

Liu, H., Z. Mi, L. Lin, Y. Wang, Z. Zhang, Z. Fawei, H. Wang, L. Liu, B. Zhu, G. Cao, X. Zhao, N. Sanders, A. T. Classen, P. B. Reich, J. S. He, 2018. Shifting plant species composition in response to climate change stabilizes grassland primary production. Proceedings of the National Academy of Sciences, 115; 4051-4056. https://doi:10.1073/pnas.1700299114

McKeon, G.M., G.S. Stone, J.I. Syktus, O. Carter, N.R. Flood, D.G. Ahrens, D.N. Bruget, C.R. Chilcott, D.H. Cobon, R.A. Cowley, S.J. Crimp, G.W. Fraser, S.M. Howden, P.W. Johnston, J.G. Ryan, C.J. Stokes, K.A. Day, 2009. Climate change impacts on northern

Australian rangeland livestock carrying capacity, Rangeland Journal, 31; 1–29. https://doi.org/10.1071/RJ08068

Mitchell, E. John, 2000. Rangeland resource trends in the United States: A technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Tech. Rep. RMRS-GTR-68. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 84 p.

Moghaddam, M., 1999. Range and Range management, Tehran University Press, 470 p.

Najafi Tireh Shabankareh, K., M. Akbarzadeh, E. Zandi Esfahan, K., Abbaszadeh, 2014. Investigation on monthly and annual changes of forage production and consumption of platychaete aucheri (Boiss.) Boiss. In the Coast of Persian Gulf and Oman Sea, Hormozgan Province, IRAN. ARPN Journal of Agricultural and Biological Science, 9; 5-70

Polley, H.W., D.D. Briske, J.A. Morgan, D.W. Wolter, J.R. Brown, 2013. Climate change and North American rangelands: Trends, projections, and implications. Rangeland Ecology and Management, 66; 493–511. https://doi.org/10.2111/REM-D-12-00068.1

Plaut, J.A., E.A. Yepez, J. Hill, R. Pangle, J.S. Sperry, W.T. Pockman, N.G. McDowell, 2012. Hydraulic limits preceding mortality in a piñon–juniper woodland under experimental drought. Plant, Cell and Environment, 35; 1601–1617.

Rashvand, S., H. Safari, P. Ashouri sanjabi, 2014. Sustainability of forage production of some rangeland species using univariate method in mountainous rangelands of Middle Alborz, Qazvin province. Iranian journal of Range and Desert Research, 19; 255-369.

Rahmani, Gh., M. Akbarzadeh, M. Sharifi yazdi, M.R. Kodoori, 2014. Seasonal variation of forage production and consumption of *Agropyron desertorum* in semi steppe rangelands of Bardsir. Journal of range Management, 1; 31-45.

Robinson, T.M.P., K.J. LA Pierre, M.A. Vadeboncoeur, K.M. Byrne, M.L. Thomey, S.E. Colby, 2013. Seasonal, not annual precipitation drives community productivity across ecosystems. Oikos, 122; 727–738. https://doi.org/10.1111/j.1600-0706.2012.20655.x

Society for Range Management. 1991. A glossary of terms used in range management. 3d ed. Society for Range Management, 2011. Denver, CO, Source: Rangeland Ecology and Management, 64; 104-108.

Sharrow, SH., 2007. Soil Compaction by grazing livestock in silvo pastures as evidenced by changes in soil physical properties. Agroforestry Systems, 71; 215-223. https://doi.org/10.1007/s10457-007-9083-4

Wesche, K., 2005. Enclosure studies indicate non-equilibrium dynamics in southern Mongolian rangelands. Ecosystems of Mongolia and frontier areas of adjacent countries: natural resources, biodiversity and ecological prospects. Proceedings of the International Conference. Ulaanbaatar (Mongolia), September, 5-9;198-200.

Yang, Y., J. Fang, W. Ma, W. Wang, 2008. Relationship between variability in above ground net primary production and precipitation in global grasslands. Geophysical research letters, 35; l23710, 4 p.

Ye, J-S, J. Reynolds, G-J. Sun, F-M. Li, 2013. Impacts of increased variability in precipitation and air temperature on net primary productivity of the Tibetan Plateau: A modeling analysis. Clime Change, 119; 321–332. https://doi.org/10.1007/s10584-013-0719-2

Zarekia, S., N. Zare, A. Ehsani, F. Jafari, H., Yeganeh, 2012. Relationship between rainfall and annual forage production of important range species (Case study: Khoshkerood –Saveh). Iranian Journal of Range and Desert Research, 19; 614-623.