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# Impact of climatic factors on forage production in Ali Abad Rangeland, Iran

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**Abstract**

The responses of four steppe forage species in the Ali Abad rangeland to precipitation timing were assessed for a period of 9 years (2004 to2012). Regression analysis was used to examine the relationship between annual production and different climatic factors. According to the results, rainfall of past year in addition to rainfall of growing season has the greatest impact on forage production in site of Ali Abad. Annual production of *Artemisia aucheri, Astragallus myriacanthus, Artemisia siberi* were most closely correlated with previous rainfall, respectively (r^2 = 0.78, 0.78, 0.81), and *Stipa barbata* with growing season rainfall (r^2 = 0.79). This study supported the use of precipitation pattern instead of the other climatic factors in effectively estimating herbage production through a statistical model.

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## Introduction

Due to extensive rangeland in Iran, measuring of forage yield is difficult in each year. Therefore, the use of indirect methods based on climate data would be useful for anticipating forage yield (Bagestani and Zare, 2007). Several studies have demonstrated the relationship between climatic fluctuation and forage yield (Duncan and Woodmansee, 1975, Pumphery, 1980, Fetcher and Trlica 1980, Hanson *et al.*, 1982, Wight *et al.*, 1984, Smoliak, 1986, George *et al.*, 1989, Hien, 2006, Bets, *et al.*, 2006 ,Ehsani *et al.*, 2007 and Mrzaali *et al.*,2011). Weather variables, especially precipitation in arid and semiarid ecosystems are the principal environmental factors influencing plant growth (George *et al.*, 1989). Composition, function and productivity of rangeland ecosystem are largely driven by yearly fluctuations in primarily precipitation. However, other factors, such as high grazing do have influence on the ecosystem (Fynn and Oonnor, 2000, Sullivan and Rohed, 2002). Precipitation pattern has a major influence on forage production on rangeland (Mclean and Smith, 1973).

The establishment of quantitative relationships between weather variables and forage production has been expressed in regression models such as described by Murphy (1970), Shiflet and Dietz (1974), Duncan and Woodmansee (1975), Fetcher and Trlica(1980), Smoliak (1986), Georg *et al.* (1989), Khumalo and Holchek (2005), Andales *et al.* (2006), and Baghestani and Zare, (2007). They explored the relationship between forage production and precipitation and demonstrated a linear equation between forage production and Weather variables. They suggested that the variations in forage production were more strongly affected by precipitation. George *et al.* (1989) reported that fall and winter precipitation, winter temperature and winter dry period patterns had a strong influence on peak standing crop. Willey *et al.* (1992) found a linear model to estimate forage production from the annual rainfall in Nigeria. Fall and winter precipitation, winter temperature, and winter dry period patterns have a strong influence on peck standing crop. According to the results of the study conducted by Ghaemi (2001), a direct relationship was found between precipitation and forage production while an inverse relationship was reported between temperature and production. Ehsani *et al* (2007) reported that rainfall indicator in growing season and previous season was a variable playing fundamental role in production. Munkhteseg *et al.* (2007) in review the effects of rainfall and high temperature in rangelands of Mongolia, stated that increasing temperature with decreasing temperature in June were the main factors reducing production in this region rangelands. Mirzaali *et al* (2011) found forage production more closely related to seasonal period precipitation instead of annual precipitation.

The present investigation focused on the relationships between climatic factors and forage production of the four native rangeland species of Ali Abad, Iran. The objective was to improve the predictability of functions relating forage production by including various climatic factors. This paper presents the results of simple correlation, regression and stepwise multiple regression analysis between various climatic factors and forage production.

## Material and methods

*Site description*

The study site was located on the Ali Abad rangeland in southwest of Yazd province (53° 52 E, 31° 36 N) at elevation of 2550 to 2700 m. Soil texture was silty loamy. The region has recognized as a semi-arid area. Average annual precipitation (January through December) based on 20-year period (1993 to 2012) is 230 mm. Most precipitation occurs as rain in the fall and winter, 70% of annual precipitations occur from October through April, 45% of annual precipitations occur in the growing season (middle February through late July). Summer is warm and dry, but shower occurs in some years. Mean annual temperature and humidity are 11.1° C and 55%, respectively. The principal forage species include *Artemisia aucheri, Astragalus myriacanthus, Artemisia sieberi, Poa bulbosa, and Hertia angustifolia.*

**Methods**

Climate data were available in Ali Abad synoptic station, about 12 km far from the Ali Abad rangeland. Climatic factors were collected during the growing season as well as different months of the year. The independent variables are listed in Table 1. Forage production data for four species of *Artemisia aucheri, Astragalus myriacanthus*, *Artemisia sieberi, Poa bulbosa* were collected from 2003 to 2012. Sampling was done based on random – systematic method along 4 transects with 200 m length and 100 m distance from each other. Sixty plots ($2m^2$) were sampled and 15 plots protected from grazing by the portable cages, were clipped, air-dried and weighed annually (Arzani and King, 1994). The portable cages were randomly distributed in large fields that were grazed by goats. Linear regression method was used to investigate the relationships between forage production and climatic factors. This model was used in previous studies (Smoliak, 1986, George *et al*., 1989, Hien, 2006, Baghestani and Zare, 2007, Ehsani *et al*., 2007). A total of 48 variables (independent variables) such as precipitation, temperature, relative humidity, sunshine and wind were used in the analysis. All independent variables and nine years forage yields were subjected to correlation analysis. Significant variables were regressed on forage yields. Stepwise multiple regressions were used to investigate the most effective variable and the most appropriate model to estimated forage yield.

**Results**

The annual dry weight forage production during study period is shown in Table 1.

**Table 1.** Forage yield of major species (kg/ha) at the Ali Abad site.

| Year | *Artemisia aucheri (kg/ha)* | *Astragalusmyri acantus (kg/ha)* | *Artemisia sieberi (kg/ha)* | *Stipabarbata (kg/ha)* | Total yield (kg/ha) |
|---|---|---|---|---|---|
| 2004 | 200 | 140 | 80 | 60 | 480 |
| 2005 | 157 | 120 | 70 | 30 | 377 |
| 2006 | 140 | 110 | 65 | 30 | 345 |
| 2007 | 150 | 120 | 65 | 50 | 385 |
| 2008 | 145 | 110 | 55 | 30 | 340 |
| 2009 | 130 | 100 | 50 | 35 | 315 |
| 2010 | 140 | 100 | 50 | 35 | 325 |
| 2011 | 145 | 110 | 65 | 30 | 350 |
| 2012 | 145 | 100 | 60 | 35 | 440 |

All climatic factors including monthly, annual, and seasonal rainfall as well as previous rainfall; monthly, annual, minimum and maximum temperature; humidity, sunshine hours and wind speed are presented in Table2 and 3.

The correlations between forage production and climatic factors are shown in Tables 4 and 5.The results showed that forage production in this region is influenced by rainfall patterns and it had no correlation with other climate factors (Tables 4 and 5).

Total production showed the correlation with rainfall in October, May, the rainfall in winter and annual rainfall. But there was a stronger correlation between total production and previous precipitation (rainfall of growing season + rainfall of years ago)(R=80). Regression equations and the estimation of total production with mentioned parameters are presented in Table 6.

The production of *Artemisia aucheri* was correlated with rainfall of October, May, winter and previous. The results of simple and multiple regressions showed that previous rainfall could explain 78% of the variations observed in the production of *Artemisia aucheri*. A correlation was found between the production of *Astragallus myriacanthus* and the rainfall of October and winter but it showed a strong correlation with previous rainfall. The simple and multiple regression equations are shown in Table 6.

The production of *Artemisia siberi* showed the correlation with rainfall in May and winter season and as well as with moisture of June month. But it had a stronger correlation with the previous season's rainfall. Results of simple and multiple regression equations are shown in Table 10.Stepwise regression showed that previous rainfall could explain about 81% of changes in production of these species (Table 6).

**Table 2.** Minimum (min), maximum (max) and mean precipitation (mm) and standard deviation (sd) at the Ali abad site on study period (2004 to 2012).

| Month | Min | Max | Mean | Sd |
|---|---|---|---|---|
| october | 0 | 0.5 | 0.05 | 0.158 |
| november | 0 | 24.9 | 7.6 | 9.30 |
| december | 0 | 78.4 | 23.03 | 23.31 |
| january | 0 | 78.2 | 20.63 | 23.64 |
| february | 3.6 | 33.3 | 19.14 | 11.30 |
| march | 2 | 39 | 14.31 | 13.47 |
| april | 2.1 | 84.8 | 33.33 | 29.77 |
| may | 0 | 6.2 | 1.98 | 2.73 |
| june | 0 | 5.6 | 1.07 | 1.87 |
| july | 0 | 2.2 | 0.99 | 1.40 |
| august | 0 | 0 | 0 | 0 |
| september | 0 | 1 | 0.1000 | 31 |
| Annual rainfall )From October to December( | 45 | 341.5 | 244.4 | 106.15 |
| Rainy of growing season )march+april+may+june( | 4 | 175 | 913.5 | 53.224 |
| Winter rainfall )january+february+march( | 54 | 185 | 115.7 | 54.65 |
| Autumn rainfall )october+november+december( | 0 | 78.4 | 30.68 | 21.114 |
| Previous rainfall ) Rainy of growing season+ Years ago) | 169.5 | 385 | 325.05 | 19.12 |

**Table 3.** Minimum(min), maximum (max) and mean tempreturen (ċ),humidity(%),wind speed.

| Climatic factors | Month | | Min | Max | Mean | sd |
|---|---|---|---|---|---|---|
| | october | | 0.6- | 38.6 | 16.87 | 1.05 |
| | november | | 8.2- | 24.4 | 10.34 | 0.694 |
| | december | | 11.8- | 19.6 | 4.6 | 1.30 |
| | january | | 17.4- | 18.6 | 2.07 | 2.09 |
| | february | | 15.6- | 21 | 5.33 | 5.95 |
| | march | | 11.2- | 27.4 | 11.72 | 1.26 |
| | april | | 5.2- | 25.6 | 17.51 | 0.87 |
| | may | | 1.2 | 32.2 | 22.41 | 1.077 |
| Temperatur | june | | 7 | 36.6 | 22.41 | 1.076 |
| (ċ) | july | | 9.8 | 38.4 | 26.54 | 0.908 |
| | august | | 5.6 | 37.8 | 25.33 | 1.55 |
| | september | | 6.2 | 36 | 22.88 | 0.816 |
| | average annual )(october to september | | 10.5 | 13.2 | 11.34 | 0.91 |
| | Absolute Minimum Annual | | 3.6 | 6.2 | 5.28 | 0.76 |
| | Absolute maximum annual | | 17.3 | 19.2 | 18.24 | 0.63 |
| Relative Humidity) %( | The average annual relative humidity | | 36 | 58.30 | 44.94 | 7.091 |
| | | march | 36 | 58 | 43.55 | 7.6 |
| | Relative humidity in | april | 28 | 56 | 43.88 | 8.14 |
| | the growing season | may | 36 | 41 | 43.33 | 3.39 |
| | months | june | 17 | 34 | 26.22 | 5.51 |
| Sunshine | | averag annual | 200.4 | 253 | 235.97 | 18.61 |
| ) hour( | Growing season | march | 205 | 257 | 230.6 | 18.21 |
| | | april | 204.5 | 295 | 255.58 | 31.202 |
| | | may | 215 | 327 | 280.1 | 35.044 |
| | | june | 265 | 365 | 328.10 | 32.67 |
| | | average annual | 9 | 14 | 11.55 | 1.6 |
| wind (km/day) | Growing season | march | 9 | 16 | 13.90 | 2.99 |
| | | april | 10 | 17 | 14 | 3.39 |
| | | may | 10 | 16 | 12.2 | 1.75 |
| | | june | 10 | 14 | 10.9 | 1.28 |

The production of *Stipa barbata* was correlated with rainfall in May and the annual rainfall. But it showed the highest correlation with the rainfall of growing season(R=79).Results of simple and multiple regression equations are shown in Table 6.Stepwise regression showed that growing season rainfall could explain 79% of changes in production of these species.

**Discussion**

The influence of climatic factors on yield of four species (*Artemisia aucheri*, *Astragallus myriacanthus*, *Artemisia siberi* and *Stipa barbata*) in the Ali Abad rangeland of Iran was studied for 9 years in a period of (2004 to2012). The linear regression model was used to determine relationship between precipitation and yield. The result of the study revealed that increasing the length of the precipitation period improved the relationship between precipitation and yield. Precipitation pattern had more strong influence on the variations of annual forage production, and various period of precipitation had different effects on annual yield of species. The various period of precipitation improved the relationship when correlated with forage production (Table 4).

**Table 4.** simple correlations ( r ) of forage yield with precipitation.

| Month | *Artemisia aucheri* | *Astragalusm yriacantus* | *Artemisia sieberi* | *Stipabarbata* | Total production |
|---|---|---|---|---|---|
| october | 0.74 | 0.67 | 0.57 | 0.58 | 0.64 |
| november | 0.39 | 0.25 | 0.18- | 0.46 | 0.3 |
| december | 0.31- | 0.52- | 0.003- | 0.53- | 0.30- |
| january | 0.20 | 0.40 | 0.46 | 0.13- | 0.28 |
| february | 0.49 | 0.32 | 0.19 | 0.70 | 0.53 |
| march | 0.60 | 0.32 | 0.43 | 0.57 | 0.7 |
| april | 0.36- | 0.25- | 0.52- | 0.18- | 0.33- |
| may | 0.74* | 0.77* | 0.75* | 0.72* | 0.73* |
| june | 0.48 | 0.44 | 0.23 | 0.37 | 0.43 |
| july | 0.28- | 0.20- | 0.32- | 0.47- | 0.33- |
| august | 0 | 0 | 0 | 0 | 0 |
| september | 0.14 | 0.36 | 0.123 | 0.13- | 0.19- |
| Annual rainfall )From October to September( | 0.61 | 0.56 | 0.54 | * 0.77 | 0.66 |
| Rainy of growing season )march+april+may+ june( | 0.48 | 0.53 | 0.51 | * 0.79 | 0.6 |
| Winter rainfall )january+february+ march( | 0.66* | 0.64* | 0.73* | 0.46 | 0.68* |
| Autumn rainfall )october+november + december( | 0.16- | 0.52- | 0.07- | 0.37 | 0.24- |
| Previous rainfall ) Rainy of growing season +Years ago( | 0.78 | 0.84** | 0.81** | 0.58 | 0.80** |

**Table 5.** simple correlations (r) of forage yield withtempreture (ċ),humidity (%),wind speed(km/day) and sunshine (hours).

| Climatic factors | month | | *Artemisia aucheri* | *Astragalus myriacantus* | *Artemisia sieberi* | *Stipabarbata* | Total production |
|---|---|---|---|---|---|---|---|
| Tempreture (ċ) | october | | 0.37 | 0.20 | 0.174 | 0.28 | 0.317 |
| | november | | 0.32- | 0.96- | 0.33- | 0.38- | 0.45- |
| | december | | 0.034 | 0.132 | 0.22 | 0247 | 0.101 |
| | january | | 0.315 | 0.302 | 0.509 | 0.012 | 0.35 |
| | february | | 0.118- | 0.303- | 0.091- | 0.094- | 0.49 |
| | march | | 0.122- | 0.309- | 0.087- | 0.081 | 0.51 |
| | april | | 0.098 | 0.57 | 0.022- | 0.015- | 0.19- |
| | may | | 0.46- | 0.399- | 0.405- | 0.092- | 0.32- |
| | june | | 0.26- | 0.393- | 0.36 | 0.313- | 0.34- |
| | july | | 0.059- | 0.024- | 0.060 | 0.023- | 0.22- |
| | august | | 0.013- | 0.022- | 0.197- | 0.188 | 0.18- |
| | september | | 0.219- | 0.364- | 0.47- | 0.36- | 0.27- |
| | average annual )october to september( | | 0.003 | 0.59 | 0.23 | 0.205- | 0.052- |
| | Absolute Minimum Annual | | 0.48 | 0.46 | 0.51 | 0.25 | 0.38 |
| | Absolute maximum annual | | 0.19 | 0.21 | 0.21 | 0.026 | 0.027 |
| Humidity (%) | The average annual relative humidity )from october to september( | | 0.16- | 0.02 | 0.10 | 0.12- | 0.13- |
| | Relative humidity in the growing season months | march | 0.10 | 0.49 | 0.19 | 0.55- | 0.15 |
| | | april | 0.20 | 0.33 | 0.217 | 0.14 | 0.26 |
| | | may | 0.42- | 0.52- | 0.35- | 0.49- | 0.3- |
| | | june | 0.53- | 0.49- | 0.73*- | 0.23- | 0.61 |
| Sunshine (hour) | averag annual | | 0.18 | 0.155 | 0.35 | 0.19- | 0.15 |
| | Growing season | march | 0.20 | 0.31 | 0.17 | 0.43 | 0.31 |
| | | april | 0.52- | 0.43- | 0.254- | 0.53- | 0.44 |
| | | may | 0.044- | 0.18 | 0.076 | 0.103- | 0.16- |
| | | june | 0.174 | 0.39 | 0.52 | 0.247 | 0.27 |
| Wind (km/day) | averag annual | | 0.158 | 0.32 | 0.212 | 0.253 | 0.005 |
| | Growing season | march | 0.128 | 0.066 | 0.154- | 0.254 | 0.064 |
| | | april | 0.294 | 0.36 | 0.441 | 0.079- | 0.122 |
| | | may | 0.161 | 0.338 | 0.304 | 0.072- | 0.158 |
| | | june | 0.378 | 0.345 | 0.332 | 0.276 | 0.552 |

**Table 6.** Regression of forage yield(Y,〖kg〗^(-1)) on precipitation(mm)at Ali abad site.

| | Regression equation | $r^2$ | P |
|---|---|---|---|
| Total forage yield(Y,$kg^{-1}$) | Y=240.89$P_{oct}+357.59$ | 0.64 | 0.032 |
| | Y=0.339$P_{annual}$+294.647 | 0.66 | 0.037 |
| | Y=0.68$P_{fall}$+291.90 | 0.68 | 0.029 |
| | +331.17 Y=18.21$P_{may}$ | 0.73 | 0.009 |
| | +183.577Y=0.576$P_{previous}$ | 0.80 | 0.005 |
| *Artemisia aucheri* (Y,$kg^{-1}$) | Y=0.268$P_{fall}+122.73$ | 0.66 | 0.035 |
| | Y=0.21$P_{oct}$+80.49 | 0.74 | 0.009 |
| | Y=7.63$P_{may}$+134.90 | 0.74 | 0.009 |
| | 80.53÷Y=0.22$P_{previous}$ | 0.78 | 0.007 |
| *Astragalusmyracantus* (Y,$kg^{-1}$) | Y=0.160$P_{fall}+95.53$ | 0.65 | 0.044 |
| | Y=0.160$P_{oct}$+111.111 | 0.67 | 0.032 |
| | +80.53 Y=0.22$P_{previous}$ | 0.78 | 0.007 |
| *Artemisia siberi* (Y,$kg^{-1}$) | Y=-1.252$H_{june}+96.15$ | 0.65 | 0.042 |
| | Y=0.3.14$P_{may}$+55.53 | 0.75 | 0.009 |
| | Y=0.148$P_{fall}$+46.40 | 0.80 | 0.005 |
| | +28.74Y=0.107$P_{previous}$ | 0.81 | 0.004 |
| *Stipabarbata* (Y,$kg^{-1}$) | Y=3.58$P_{may}+30.79$ | 0.75 | 0.010 |
| | Y=0.090$P_{annual}$+19.34 | 0.77 | 0.009 |
| | +22.81 Y=0.183$P_{growing}$ | 0.79 | 0.007 |

Results of this research showed that rainfall of past year in addition to rainfall of growing season had the greatest impact on forage production in site of Ali Abad of Yazd. The reason for a high correlation between species production of *Artemisia aucheri*, *Astragallus myriacanthus*, *Artemisia siberi* and total production is that the mentioned species and most species found in the study site were shrub with deep roots. Therefore, not only the rainfall of that same year, but rainfall in the previous year is able to be absorbed by their roots. Abdullahi *et al* (2010) found that rainfall of previous season had impact on rangeland production. Ehsani *et al* (2007) reported that rainfall indicator in growing season and previous season had the greatest impact on production. Because winter reduces the temperature and limits the growth of the species; therefore, plants are not able to use the winter rainfall. Also, results showed that the species *Stipa barbata* had a robust correlation with growing season rainfall. Because roots level of this grass penetrates up to 30 cm of soil depth and can use the amount of water saturated in this depth. Therefore, much more rainfall outside of the growing season had no impact on plant growth. Studies of Abdullahi *et al* (2010) confirmed the results of this research.

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