Investigation of Relationship between Precipitation and Temperature with Range Production of Grasslands in North and North-east of Iran

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\textbf{Abstract.} One of the most important issues in rangeland management is the estimation of carrying capacity. To estimate range production, we need to use a large number of sample plots to clip plants in a sampling scheme; therefore, due to vast area of rangelands and time and cost limitations, direct estimation of rangeland production by sampling plots is almost impossible. Since there is a strong relationship between climatic factors and rangeland production, using indirect estimation methods of rangeland production is important. The relationship between production samples and climatic factors can be easily predicted. Present study was conducted in five locations of Spandol, Zarchak, Torogh, Aselme, and Dash, Iran in 2013. In this research, the relationships between forage production and three climate parameters including precipitation, temperature, and precipitation to temperature ratio (P/T) were investigated. For each parameter, 33 variables (periods) were considered. Stepwise regression analysis was used to select the most effective periods of precipitation and temperature. The relationship between production and March to April precipitation and November to December temperature was positive but with October to March temperature, it was negative. The relationship between production and P/T was negative in May to June and positive in January to March. In general, simultaneous of rainfall and temperature had effective roles in increasing dry matter production of grasslands in the studied areas.

\textbf{Key words:} Rainfall, Regions, Rangeland production, Climate conditions
Introduction
From viewpoint of national economics, rangeland production is very important and is one of the main objectives of range management plans for ranchers. In addition, production as an ecological and management indicator is used in the most rangeland measurement and monitoring projects. Rangeland production is the aerial biomass of vegetation and usually is defined in kg/ha (Bonham, 2013; Arzani and Abedi, 2015). Because of vast area of rangelands and limitations of time and cost, direct measurement of rangeland production is time-consuming, so indirect methods are used to estimate rangeland production (Cook and stubbendieck, 1986). Since there is a strong correlation between climatic factors and rangeland production, understanding the relationship between vegetation and climatic factors is a prerequisite for applying correct management methods in rangeland ecosystems (Sharifi and Akbarzadeh, 2013; Holecheck et al., 2004; Mohammadi et al., 2015). Given that meteorological parameters are measurable; these relationships can be easily predicted. Among the factors of climate, precipitation is the most effective indicator for determining the rangeland production (Hahn et al., 2005; Naderi, 2007) and the second important factor is temperature which its interaction with precipitation effectively determines rangeland production (Munkhtsetseg et al., 2007; Smart et al., 2007).

Although the influence of climatic factors on vegetation has been confirmed for several years by range researchers, few studies have been conducted on the effect of these factors on the rangeland production. On the other hand, the effects of short-term climate changes on vegetation structure and its performance have not been studied intensively.

According to the strong relationships among climatic factors and rangeland production in different periods of seasons, it is required to recognize effective factors in forage produced in each location for livestock feeding. These kinds of information are especially important in drought situation when rangelands are in shortage of forage and severe grazing.

Many researchers have attempted to estimate the mean rangeland production through the past climatic data. In this context, we can refer to Hart and Carlson (1975), Abdollahi et al. (2006, 2011) and Murphy (1970). They predicted the rangeland long-term production by precipitation and showed that there were direct relationships between annual forage production and rainfall. Ehsani et al. (2007) in a study on the impact of climatic conditions on vegetation in rangeland of Saveh considering the climatic indices of annual rainfall, growing season rainfall, previous rainfall, and temperature showed that fluctuation of climatic indices during the climatic periods had a significant effect on rangeland production. Zarekia et al. (2012) had also approved that in steppe vegetation of central Province, Iran in the growing season, recent and previous rainfall indices were the most effective indicators of shrub production. Similarly, combination influence of precipitation and temperature on production has been emphasized by many other authors (Bayat et al., 2016 a ; Bayat et al., 2016 b; Munkhtsetseg et al., 2007; Ehsani et al., 2007; Abdollahi et al., 2011; Britta et al., 2010).

Bayat et al. (2016a) in steppe rangelands of Esfghan province, Iran concluded that the October temperature with February to April rainfall was the best estimator of annual production. Abtahi et al. (2014) in an investigation on vegetation dynamics and range conditions in central desert of Iran reported that due to the weather conditions of desert, the amount of
vegetation and its variation were affected by the precipitation changes. Various studies have been done on the impact of climate factors on rangeland production. Rainfall performance data of previous years have also been investigated for predicting forage production, which showed that there was a linear relationship between the rainfall of this year and rainfall of two years ago (Ehsani et al., 2007; Smart et al., 2007).

Kohestani and Yeganeh (2016) studied the effects of Range Management Plans (RMP) on vegetation of summer rangelands in Mazandaran province, Iran. Their results showed that the RMP had increased the available forage production up to 14.7%. Hadian et al. (2013) had studied the effect of rainfall on vegetation changes in Semirom and Lordegon regions of Iran. Their results showed that the effect of rainfalls differed in various regions depending on plant growth form and ecological conditions. Therefore, the rangeland vegetation had the highest correlation with the spring rainfall and was related to the annual rainfall in the forest area. Smart et al. (2007) for modeling forage production using rainfall from 1945 to 1960 showed that there were relationships between forage production with recent and previous spring rainfall. The results showed that the rainfall of March and growing season were the most effective indicators in production and cover of grass species and showed a positive and significant correlation. Jagerbr and et al. (2009) investigated the plant communities in Sudan. Their results showed that different plant communities responded differently to the amount of rainfall.

Koc (2001) in his studies on high elevation of Turkey areas showed that autumn rainfall had more decisive effect on rangeland production than the rainfall of other seasons. Fall drought did not affect grass production, but it reduced the growth of legumes.

The period of high temperatures could limit plant growth without a significant reduction in the amount of rainfall. Therefore, simultaneous analysis of the two climate variables of rainfall and temperature is necessary. (Munkhtsetseg et al., 2007). Martin et al. (1995) studied the effect of climate on the forage production of Cenchrus ciliaris in the Sonoran desert of California and concluded that there was a significant relationship between amount of summer rainfall and production. But, due to temperature limitation of plant growth in winter, there was no significant relationship between winter rainfall and plant growth.

The objective of this study was to investigate relationship between rangeland production and some major climatic factors such as precipitation and temperature characteristics and precipitation to temperature ratio (PTR) using regression analyses. The best fitted model of prediction was selected for rangeland production of all locations.

Materials and Methods

Study location

The major climatic factors such as precipitation and temperature characteristics and data of rangelands production were collected at five locations in different climatic conditions of Iran in 2013 (Fig. 1).
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Fig. 1. Geographic location of study area

The main characteristics of study area and their vegetation are summarized in Tables 1 and 2. It should be noted that the dominant coverage of these five areas were perennial grasses which in comparison to other life forms, clipping of grasses is easy and precise.

Table 1. The main Characteristics of study areas in north and norther Iran.

<table>
<thead>
<tr>
<th>Province</th>
<th>Location</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Elevation (m)</th>
<th>Precipitation (mm) 2013</th>
<th>Soil texture</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilan Zarchak</td>
<td>50° 04' 18&quot;</td>
<td>36° 55' 00&quot;</td>
<td>2000</td>
<td>285</td>
<td>Clay loam</td>
<td>Flat</td>
<td></td>
</tr>
<tr>
<td>Gilan Spandol</td>
<td>48° 54' 15&quot;</td>
<td>37° 17' 39&quot;</td>
<td>1970</td>
<td>706</td>
<td>Clay loam</td>
<td>Flat</td>
<td></td>
</tr>
<tr>
<td>Khorasan Razavi Torogh</td>
<td>59° 32' 10&quot;</td>
<td>36° 08' 56&quot;</td>
<td>1240</td>
<td>204</td>
<td>Clay loam</td>
<td>North Faced</td>
<td></td>
</tr>
<tr>
<td>Khorasan Razavi Aselme</td>
<td>58° 29' 56&quot;</td>
<td>37° 38' 24&quot;</td>
<td>1720</td>
<td>322</td>
<td>loam</td>
<td>North Faced</td>
<td></td>
</tr>
<tr>
<td>Northern Khorasan Dasht</td>
<td>56° 03' 21&quot;</td>
<td>37° 19' 04&quot;</td>
<td>1090</td>
<td>150</td>
<td>Clay loam</td>
<td>Flat</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Dominate and accompanied species of five study areas.

<table>
<thead>
<tr>
<th>Province</th>
<th>Location</th>
<th>Dominate species</th>
<th>Accompanied species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilan Zarchak</td>
<td>Bromus sp., Hordeum bulbosum</td>
<td>Stachys inflata, Achillea santhnia</td>
<td></td>
</tr>
<tr>
<td>Gilan Spandol</td>
<td>Bromus sp., Trifolium repens</td>
<td>Alchemilla vulgaris, Agropyron trichophorum</td>
<td></td>
</tr>
<tr>
<td>Khorasan Razavi Torogh</td>
<td>Stipa barbata, Poa bulbosa</td>
<td>Haplophyllum perforatum, Cousinia eringiodes</td>
<td></td>
</tr>
<tr>
<td>Khorasan Razavi Aselme</td>
<td>Festuca ovina, Agropyron trichophorum</td>
<td>Asperula orientalis, Agropyron intermedium</td>
<td></td>
</tr>
<tr>
<td>Northern Khorasan Dasht</td>
<td>Agropyron trichophorum, Aegilops crassa</td>
<td>Noaea mucronata, Poa bulbosa</td>
<td></td>
</tr>
<tr>
<td>Khorasan</td>
<td>Dasht</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sampling Method
Based on an international protocol (Fraser et al., 2014), two-macro plots of 64 m² (8 x 8 m) were established in each location (Fig. 1). Then, in each location, forage production of 64 plots was clipped, air dried and weighed. The clipping procedure includes cutting of all aerial parts of plants to the ground surface. For woody shrubs, only current year growth was clipped. A macro plot of 640 1m² was built in each site and considered as unit of experiment.

Data were collected using methods of Esmaeil Nia (2015), and Fakhar et al. (2015). Climatic data included monthly cumulative precipitation and temperature in 2013 collected in nearby stations (www.weather.ir).

Data Analyses
In this study, we have modeled forage production as a response variable versus predictive variables of monthly cumulative precipitation, temperature (Mohammadi et al., 2015) and precipitation to temperature ratio.

In the first step, the periods of one to nine were specified, which may affect production (Table 3). The statistical model of this research is as follows (Eq. 1) (Steel et al., 1997):

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \quad (1) \]

Where:
\( X = \) Independent variable of precipitation \( P \), temperature \( T \), \( P/T \).
\( Y = \) dependent variable of forage production.
\( \beta_0, \ldots, \beta_n = \) regression coefficients,
\( \varepsilon = \) residuals of model.

To select the best model, we have used stepwise regression. All data were analyzed using Minitab, v.18.

Table 3. Different climatic periods as independent variables and their symbols that affecting range production.

<table>
<thead>
<tr>
<th>Periods (months)</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>X1</td>
</tr>
<tr>
<td>2 months</td>
<td>X2</td>
</tr>
<tr>
<td>3 months</td>
<td>X3</td>
</tr>
<tr>
<td>4 months</td>
<td>X4</td>
</tr>
<tr>
<td>6 months</td>
<td>X6</td>
</tr>
<tr>
<td>9 months</td>
<td>X9</td>
</tr>
</tbody>
</table>

* Xij, where i= define as 1 to 9 cumulative growing season from 1 month to 9 months
j= define as1= Oct to 9 = June. X= variables of precipitation (P), temperature (T) and (PT) ratio

Results
The mean production for each location is presented in Table 4. The collected data were subjected to stepwise regression involving cumulative data of precipitation (P), temperature (T) and PTR as independent variables (33 variables) (Table3) and forage production as dependent variables (Table4). The result of stepwise regression analysis using 66 variables of precipitation (P), temperature (T) is presented in Tables 5 and 6. The validity of model was tested based on significance of F test (p<0.01) coupled with lower VIF (< 10) and higher coefficient of determination \( R^2 = \) close to 100%.

Table 4. The mean dry matter production of study area, Iran.

<table>
<thead>
<tr>
<th>Province</th>
<th>Location</th>
<th>Mean production (kg/ha) in 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilan</td>
<td>Zarchak</td>
<td>649</td>
</tr>
<tr>
<td>Gilan</td>
<td>Spandol</td>
<td>963</td>
</tr>
<tr>
<td>Khorasan</td>
<td>Torogh</td>
<td>1268</td>
</tr>
<tr>
<td>Razavi</td>
<td>Aselme</td>
<td>3331</td>
</tr>
<tr>
<td>Razavi</td>
<td>Northern</td>
<td>1454</td>
</tr>
<tr>
<td>Khorasan</td>
<td>Torogh</td>
<td>1268</td>
</tr>
<tr>
<td>Razavi</td>
<td>Aselme</td>
<td>3331</td>
</tr>
<tr>
<td>Gilan</td>
<td>Spandol</td>
<td>963</td>
</tr>
<tr>
<td>Khorasan</td>
<td>Torogh</td>
<td>1268</td>
</tr>
<tr>
<td>Razavi</td>
<td>Aselme</td>
<td>3331</td>
</tr>
<tr>
<td>Razavi</td>
<td>Northern</td>
<td>1454</td>
</tr>
<tr>
<td>Khorasan</td>
<td>Torogh</td>
<td>1268</td>
</tr>
</tbody>
</table>
The Fitted model is as follows:

\[-379.84 + 0.217 P_{27} + 172.96 T_{23} - 111.97 T_{66}\]

(2)

In final model, the cumulative precipitation Mar. and Apr. (P_{27}), and temperature data Nov. and Dec. (T_{23}) Oct. to Mar. (T_{66}) were entered in the final model (R^2=99%) (Table 5). The model indicated that 99% of the production variation was positively affected by rainfall in March to April, coupled with higher temperature in November to December. In contrast, the relationship between Y and T_{66} was negative indicating that the increase of temperature in winter (Oct. to Mar.) had negatively reduced rangeland production (Eq. 2) (Table 5). The significance of the regression coefficient showed that a part of variation in the production of forages was due to variation in rainfall and temperature.

The cumulative data of precipitation to temperature ratios (P/T) of 9 periods were entered in repression model for estimate of production. Result of stepwise regression analysis is summarized in Table 6. Result indicated that two variables of P/T ratio in May and Jun (P/T_{29}) and P/T ratio of January to March (P/T_{36}) were entered in the final model (Eq. 3) (Table 6).

\[
y = 206.9 - 81.5 P_{29} + 19.86 P_{36}
\]

(3)

The cumulative precipitation and temperature ratio in May and Jun (P_{29}) were similar in January to March (P_{36}). The relationship between Y and P_{29} was negative but with P_{36}, it was positive. This result indicated that lower precipitation coupled with higher temperature in spring let the reduction in forage production and in contrast, higher precipitation with lower temperature in winter may increase production. The higher value of R^2=93% of production variation was affected significantly by precipitation to temperature ratio in May and June in January to March (Eq. 3) (Table 6).

**Discussion and Conclusion**

As the result of our model indicated, there was a positive relationship between productions of March to April, which our results conformed the benefits of herbaceous grasses in this period (Table 5) (Mesdaghi, 2015; Holecek et al., 2005; Westoby, 1979; Hosseni et al., 2003; Akbarzadeh et al., 2007). Winter and early spring rainfalls are effective because the precipitation is more likely to penetrate deep into the soil (Mesdaghi, 2015).

Fall and early winter precipitations were eliminated from our model because the moisture of this period is more effective for shrubs with deep roots than grasses with surface roots. Winter precipitation that is usually happened in the form of snow benefits perennial species while spring rainfall is more useful for annual species (Westoby, 1979).
Summer rainfall before penetrating into the soils will be evaporated, so precipitation in summer was not entered in period of our model.

Fall precipitation was eliminated from the model because it was not more effective in plant production than rainfall of other seasons (Baghestani and Zare, 2007; Mesdaghi, 2015; Hanson et al., 1982; Jabbogy and Sala, 2000). However, the rainfall of growing season is more effective for the growth of herbaceous plants (Hosseini et al., 2003; Akbarzadeh et al., 2007; Zare Kia et al., 2012; Kbumalo & Holecheck, 2005, Ehsani et al., 2007). The positive relationship of temperature in November and December had no effects on the production of grasses, which was not simultaneous with precipitation period. In contradiction to our results, in some other studies, the impact of December temperature on the production of annual species has been confirmed (Bayat et al., 2016 a).

Our result shows that range production is more affected by precipitation and temperature separately than the ratio of two factors because temperature and precipitation separately had higher share in the model. In final, these two factors played an important role in estimation of production.

In conclusion, when the temperature is favorable, dominated grasses of rangelands with bunch form and extended root system can efficiently absorb more moisture from each event of rainfalls. It is important to note that the data of this research belonged to one year period; therefore, the results could not be generalized in long terms.

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بررسی ارتباط بین بارش و دما با تولید علفزارهای شمال و شمال شرق ایران

فکر از اقدامات مهم در مدیریت مراتع براورد ظرفیت جریایی مراتع است و چون برآورد بارود نیازمند قطع پلات های زیادی است، بنابراین با توجه به سطح و عمق مرتع ایران و محدودیت زمان و بودجه، برآورده مستقیم تولید مراتع از طریق تعادل زیاد پلات میسر نیست به همین دلیل کاربرد روش های غیرمستقیم مهم است و از انجایی که رابطه قوی بین عوامل اقلیمی و تولیدات مراتع وجود دارد، بنابراین می توان ارتباط زیاد و عوامل اقلیمی را به راحتی پیشینه کرد. مناطق مورد مطالعه در این تحقیق شامل مراتع بین منطقه اسنندول، زرچاک، طراق، آسته و دشت می باشند که نمونه گیری از آنها در سال 1392 انجام شد. در این تحقیق ارتباط تولید با سه پارامتر بارندگی و دما و نسبت بارندگی به دما بررسی شد. برای هر پارامتر 33 دوره زمانی در نظر گرفته شد. نتایج تحلیل نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد. نتایج نشان داد تولید با بارش افزایش و در نتیجه رگرسیون گام به گام استفاده شد.