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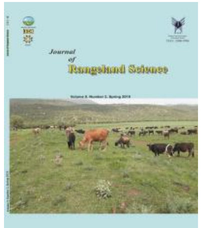

Research and Full Length Article:

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

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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.

Key words: Rainfall, Regions, Rangeland production, Climate conditions

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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 Esfehan 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

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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 Sonuran 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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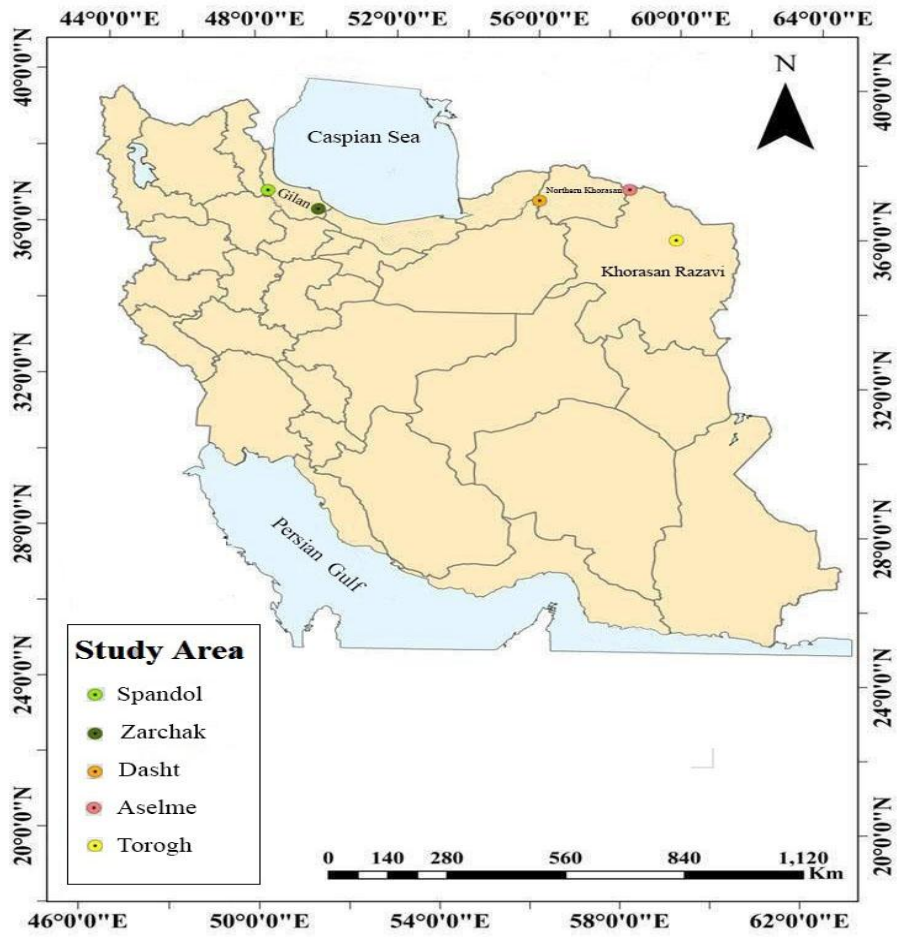

Fig. 1. Geographic location of study area

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.

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

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

Province	Location	Dominate species	Accompanied species
Gilan	Zarchak	*Bromus sp., Hordeum bulbosum*	*Stachys inflata, Achillea santhnia*
Gilan	Spandol	*Bromus sp., Trifolium repens*	*Alchemilla vulgaris, Agropyron trichophorum*
Khorasan Razavi	Torogh	*Stipa barbata, Poa bulbosa*	*Haplophyllum perforatum, Cousinia eringiodes*
Khorasan Razavi	Aselme	*Festuca ovina, Agropyron trichophorum*	*Asperula orientalis, Agropyron intermedium*
Northern Khorasan	Dasht	*Agropyron trichophorum, Aegilops crassa*	*Noaea mucronata, Poa bulbosa*

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Sampling Method

Based on an international protocol (Fraser *et al.*, 2014), two-macro plots of 64 m^2 (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 1m^2 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):

$$Y = \beta_0+\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \quad (1)$$

Where:

X = Independent variable of precipitation (*P*), temperature (*T*), *P/T*.

Y= dependent variable of forage production.

$\beta_0 \dots, \beta_1$ =regression coefficients,

ε =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.

1 month	Sym*	2 months	Sym	3 months	Sym	4 months	Sym	6 months	Sym	9 months	Sym
Oct.	X_{11}	Oct.-Nov.	X_{22}	Oct.-Dec.	X_{33}	Oct.-Jan.	X_{44}	Oct.-Mar.	X_{66}	Oct.-Jun.	X_{99}
Nov.	X_{12}	Nov.-Dec.	X_{23}	Nov.-Jan.	X_{34}	Nov.-Feb.	X_{45}	Jan.-Jun.	X_{69}		
Dec.	X_{13}	Dec.-Jan.	X_{24}	Dec.-Feb.	X_{35}	Dec.-Mar.	X_{46}				
Jan.	X_{14}	Jan.-Feb.	X_{25}	Jan.-Mar.	X_{36}	Jan.-Apr.	X_{47}				
Feb.	X_{15}	Feb.-Mar.	X_{26}	Feb.-Apr.	X_{37}	Feb.-May.	X_{48}				
Mar.	X_{16}	Mar.-Apr.	X_{27}	Mar.-May.	X_{38}	Mar.-Jun.	X_{49}				
Apr.	X_{17}	Apr.-May.	X_{28}	Apr.-Jun.	X_{39}						
May.	X_{18}	May.-Jun.	X_{29}								
Jun.	X_{19}										

* 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.

Province	Location	Mean production (kg/ha) in 2013
Gilan	Zarchak	649
Gilan	Spandol	963
Khorasan Razavi	Torogh	1268
Khorasan Razavi	Aselme	3331
Northern Khorasan	Dasht	1454

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Table.5 Analysis of variance of stepwise regression using 66 variables of precipitation (P), temperature (T) as independent variables and forage production as dependent variables.

Variables in final models	Abbreviation	F test	VIF	R^2
Precipitation Mar. and Apr.	P_{27}	1285.09**	1.25	
Temperature Nov. and Dec.	T_{23}	45458.49**	9.13	
Temperature Oct. to Mar.	T_{66}	15084.70**	9.86	0.99

** =significant at 5% probability level

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).

Table.6 Analysis of variance of stepwise regression using 33 variables of precipitation temperature ratios (P/T) as independent variables and forage production as dependent variables.

Variables in final models	abbreviation	F	VIF	R^2
P/T ratio in May and Jun.	P/T_{29}	23.80*	3.62	
P/T ratio in January to March	P/T_{36}	44.22*	3.62	93.18

* =significant at 5% probability level

The Fitted model was as follows

$$y = 206.9 - 81.5P/T_{29} + 19.86P/T_{36} \quad (3)$$

The cumulative precipitation and temperature ratio in May and Jun (P/T_{29}) were similar in January to March (P/T_{36}). The relationship between Y and P/T_{29} was negative but with $P/T_{36,}$ 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; Holeckek *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).

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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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چکیده. یکی از اقدامات مهم در مدیریت مراتع برآورد ظرفیت چرایی مرتع است و چون برآورد تولید مرتع نیازمند قطع پلات‌های زیادی است، بنابراین با توجه به سطح وسیع مراتع ایران و محدودیت زمان و بودجه، برآورد مستقیم تولید مراتع از طریق تعداد زیاد پلات میسر نیست به همین دلیل کاربرد روش‌های غیرمستقیم مهم است و از آنجایی که رابطه قوی بین عوامل اقلیمی و تولیدات مرتع وجود دارد، بنابراین می‌توان ارتباط تولید و عوامل اقلیمی را به راحتی پیش‌بینی کرد. مناطق مورد مطالعه در این تحقیق شامل مراتع پنج منطقه اسپندول، زرچاک، طرق، آسلمه و دشت می‌باشند که نمونه گیری از آنها در سال ۱۳۹۲ انجام شد. در این تحقیق ارتباط تولید با سه پارامتر بارندگی و دما و نسبت بارندگی به دما بررسی شد. برای هر پارامتر ۳۳ دوره زمانی در نظر گرفته شد. برای انتخاب موثرترین دوره‌های بارش و دما از آنالیز رگرسیون گام به گام استفاده شد. نتایج تحلیل نشان داد تولید با بارش اسفند و فروردین و دمای آبان و آذر رابطه مستقیم و با دمای مهر تا اسفند همبستگی معکوس داشت. تولید با نسبت بارش به دما با داده‌های دی تا اسفند رابطه مستقیم و با نسبت بارش به دمای اردیبهشت و خرداد همبستگی معکوس داشت. به طور کلی همزمانی بارش بهار با افزایش دما نقش موثری در افزایش تولید علفزارها دارد به طوری که بیشترین نقش در برآورد تولید به این دو عامل بستگی دارد.

کلمات کلیدی: بارندگی، مناطق، محصول علوفه، شرایط اقلیمی

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