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Research and Full Length Article:

Investigation of Climatic Parameters Affecting Annual Forage Production in BidAlam Rangeland, Abadeh, Fars Province, Iran

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Abstract. Regardless the crop production, range and livestock management is unlikely to be possible. Considering the range production is essential for efficient and effective range management. This study aims to investigate the relationship between the rate of forage production and the effects of climate variables. For this purpose, forage yield of four range species including *Artemisia sieberi*, *Scariola orientalis*, *Stipa atriseta*, and *Stachys inflate* regarded as indices species was recorded in Bidalam rangeland, Fars province, Iran in a 10-year period (1998 to 2007) and then, the study continued for another two years (from 2016 to 2017). Forage yield was collected through cutting and weighing method in 60 random 2m^2 plots along four 300 m transects during 12 years. Climatic parameters such as rainfall, temperature, relative humidity and sunshine periods were obtained from Abadeh weather station and used for estimation of forage yield in different growth periods of the year. The annual dry matter production of each species and sum of all species were used as dependent variables and climatic parameters were considered as independent ones using multivariate linear regression. The results showed that previous rainfall (rainy of growing season plus last year) had the highest effect on annual forage production of rangelands (R^2=0.88). It was concluded that using regression analysis between annual rainfall and forage production in some indices species, the rangeland production of coming years could be estimated with high accuracy.

Key words: Rainfall, Temperature, Forage production, Steppe rangelands

Introduction

Describing how resource availability modifies ecosystem structure is a long-standing ecological challenge and increasingly more important given the uncertainties surrounding climate change. Water availability is a strong driver of plant community structure in a number of systems (Noy-Meir 1973; Westoby *et al.*, 1989), leading to shifts in species diversity and composition over time (Cleland *et al*., 2013). Considering long-term production is essential for better forage management of rangelands. Application of climatic data could be a solution to predict long-term rangeland production. Therefore, the use of indirect methods based on climate data would be useful to predict forage yield (Baghestani 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; Smoliak, 1986; George *et al*., 1989; Hien, 2006; Bets *et al*., 2006; Ehsani *et al*., 2007; Mirzaali, 2011; and Fakhimi, 2014). 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 ecosystems are largely driven by yearly fluctuations in abiotic drivers, primarily precipitation. However, other factors such as overgrazing have an influence on the ecosystem (Fynn and Connor, 2002; Sullivan and Rohed, 2002). Precipitation pattern has a major effect on forage production on rangeland (Mclean and Smith, 1973). Mohammadi Moghadam *et al*., (2013) modeled forage production using temperature parameters and evapotranspiration in the Polouer site, Mazandaran province, Iran. Based on the results, the model derived from evapotranspiration could provide a better estimation of forage production in this area. However, they observed that in certain periods, the temperature and the average temperature were also effective in range production. The relationship between weather variables and forage production has been expressed in regression models (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; Baghestani and Zare, 2007; Fakhimi *et al*., 2019 ; Fakhar Izadi *et al*,. 2019). They all concluded 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 impact on peak standing crop. Willey *et al.*, (1992) also found a linear model to estimate forage production from the annual rainfall in Nigeria. Ehsani *et al.*, (2007) reported that in an arid environment, rainfall indicator in growing season and previous season variables played a fundamental role in production of some shrub species. Munkhteseg *et al*,. (2007) studied the effects of rainfall and high temperature and stated that increasing temperature with decreasing rainfall in June was the main factor reducing production in rangelands of Mongolia. Mirzaali, (2011) also found forage production more closely related to seasonal period precipitation instead of annual precipitation. The present research focused on the relationships between climatic parameters and forage production of four native rangeland species such as *Artemisia sieberi*, *Scariola orientalis*, *Stipa atriseta*, and *Stachys inflate* in rangeland of Bid Alam in Fars province, Iran. The objective was to improve the predictability of forage production based on different climatic parameters.

Materials and Methods

Site description

The study site is located on the Bid Alam rangeland in southwest of Abadeh, north of Fars province (52° 28 E, 31° 18 N) at an altitude of 2100 m. Soil texture was silty loam. The region is recognized as a semi-arid area. Mean annual precipitation based on a 25-year period (1993 to 2017) was 126 mm. Most precipitation occurs as rain in the fall and winter, 55% of annual precipitation occurs from October to April, and 43% of precipitation occurs in the growing season (middle February to late July) in the region. Mean annual temperature is 14.2°C and relative humidity mean was 11%. The soil of the study area was relatively deep with a light to moderate texture, moderate drainage, pH of 7.5, and 45% stone ad gravel. *Artemisia sieberi*, *Scariola orientalis*, *Stipa atriseta*, and *Stachys inflate* were the principal forage species.

Research Methods

Climatic parameters were summed for months of the year, the growing season, and the different combinations. The independent variables are listed in Table 1. The forage production data of *Artemisia sieberi*, *Scariola orientalis*, *Stipa atriseta*, and *Stachys inflate* were recorded in a national project performed by the Research Institute of Forests and Rangelands, Iran during 1988-2007 as well as the data recorded during 2016-2017 for two years, totaling 12 years. Sampling was done based on a random systematic method along four transects with 300 m length and 100 m distance from each other. Sixty plots (2m²) 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 grazed by goats. Linear regression method was used to investigate the relationship between forage production and climatic factors. This model was also tested in other areas by (Smoliak, 1986; George *et al*., 1989; Hien, 2006; Baghestani and Zare, 2007; Ehsani *et al.*, 2007; Mirzaali, 2011; Abdollahi *et al.*, 2011; and Fakhimi, 2014). A total of 42 variables (independent variables) such as precipitation, temperature, relative humidity, and sunshine were used in the analysis. All independent variables and 12 year forage yield were subjected to stepwise multiple regression analysis and the most effective variables were determined to estimate forage yield.

Results

The annual forage production during the study period varied from a low of 79 kgh^{-1} to a high of 605 kgh-1 the higher production belonged to *Artemisia sieberi* and *Stipa atriseta*, respectively (Table 1).

Descriptive statistical parameters of climatic factors such as minimum, maximum, mean temperature (°C) relative humidity (%), sunshine (hours) and standard deviation of Bid Alam site over 12 years are presented in Table 2.

Descriptive statistical parameters of precipitation such as mean, minimum, maximum of individual months and combination of several months of growing season and Total annual rainfall of the growing season of the same year and pervious year are presented in Table 3.

Table 1. Forage yield of species in the Bid Alam site

Years	Forage yield (kgh^{-1})				
	Artemisia sieberi	*Scariola orientalis*	*Stipa atriseta*	*Stachys inflata*	Total yield
1998	419	73	13	5	505
1999	388	75	11	87	561
2000	62	2	5	11	79
2001	91	4	6	17	117
2002	234	243	31	98	605
2003	111	3	5	14	129
2004	238	5	5	6	246
2005	361	0	3	35	398
2006	221	30	6	41	299
2007	395	20	5	143	562
2016	378	78	5	98	557
2017	368	91	5	70	534

Table 2. Descriptive statistical parameters of Minimum (Min), Maximum (Max) and mean temperature (°C) Relative Humidity (%), and sunshine (hours) and standard deviation (SD) in the Bid Alam site during the study period (1998 to 2007 and 2016 to 2017)

Climatic factors	Months	Min	Max	Mean	sd
Temperature (°C)	October	15.2	17.9	16.9	0.8
	November	9.9	12.4	11.2	0.8
	December	1.6	8.4	5.5	1.8
	January	-0.9	6.4	3.4	2.3
	February	1.5	6.5	3.9	1.5
	March	11.1	13.4	12.4	0.9
	April	3.4	9.4	7.7	1.7
	May	20.4	24.2	22.1	1
	June	24.5	27	26	0.8
	July	23	26	24.6	0.9
	August	20.5	23.2	22.2	0.9
	September	15.2	17.9	16.9	0.8
	Annual Average	13.7	15.1	14.4	0.5
	Absolute Annual Min	-0.9	5.1	2.7	1.8
	Absolute Annual Max	25.1	27	26.1	0.6
Relative Humidity (%)	Annual Average (RH%)	28	41	34.9	3.8
	March RH%)	28	56	40	7.6
	April RH%)	29	52	39.9	7.3
	May RH%)	26	40	32.5	4.9
	June RH%)	14	33	22.8	5.6
Sunshine (hour)	Annual Average	155.6	402	283.8	7.1
	March	208.2	295.8	254.4	26.2
	April	211.6	294.7	257.9	24.5
	May	234.4	335.2	302.9	29.1
	June	317	402.8	357.5	24

Table 3. Minimum (min), maximum (max) and mean precipitation (mm) and standard deviation (SD) at the Bid Alam site during the study period (1998 to 2007 and 2016 to 2017).

Months	Min	Max	Mean	Sd
October	0	3.0	0.6	1.1
November	0	26.9	5.7	8.9
December	0.1	91.4	27.1	34.3
January	0	116.8	27.9	36.2
February	1	34.4	14.8	11.3
March	0	76.6	14.5	21.6
April	0.3	62.9	20.9	20.4
May	0.01	49	9.2	13.2
June	0	5.8	1.0	2.2
July	0	6.2	1.0	2.3
August	0	3.5	0.7	1.3
September	0	0.01	0.0	0.0
Annual rainfall From Oct. to Dec.	2.2	93.6	33.5	34.1
Rainfall of growing season (Mar+Apr+May+Jun)	13.1	94.7	45.7	26.4
Winter rainfall (Jan+ Feb+Mar)	4.4	108.9	51.4	30.0
Autumn rainfall (Oct to May)	62.0	261.0	120.9	62.6
Total rainfall of the growing season and last year	63.5	468.6	231.2	11.8

The results of correlations between forage production and precipitation of individual months and combination of several months of growing season for individual species yield and annual total production are presented in Table 3. Production of *Artemisia sieberi* showed a correlation with rainfall in September, December and annual rainfall. However, it showed a stronger correlation with the annual precipitation plus previous year. For *Scariola orientalis*, there was a significant correlation between forage yield and precipitation amounts of January, May and annual precipitation in previous year. For *Stipa atriseta*, there were significant correlations between forage yield and precipitation amounts of October and rainy of growing season from March to June. For *Stachys inflate*, there were significant correlations between forage yield and precipitation amounts of October precipitation and annual precipitation in previous year. For annual total production, there were significant correlations forage yield and precipitation amounts of December and annual precipitation in previous year. It was concluded that forage production in this region is influenced mainly by rainfall patterns and no correlation with other climate factors (Table 4).

Table 4. Simple correlations (r) of forage yield with precipitation at the Bid Alam site

Month	*Artemisia sieberi*	*Scariola orientalis*	*Stipa atriseta*	*Stachys inflate*	Total production
October	0.23	0.30	0.61*	0.65*	0.09
November	0.52	0.03	0.16	0.10	0.33
December	0.73*	0.46	0.27	0.55	0.78*
January	0.51	0.68*	0.30	0.53	0.64
February	0.18	0.39	0.41	0.08	0.29
March	0.07	0.16	0.29	0.40	0.16
April	0.10	0.03	0.09	0.30	0.20
May	0.33	0.64*	0.30	0.29	0.30
June	0.34	0.31	0.28	0.37	0.19
July	0.17	0.25	0.19	9.26	0.07
August	0.03	0.19	0.03	0.51	0.17
September	0.76*	0.21	0.14	0.32	0.22
Rainfall (From Oct to May)	0.59	0.36	0.14	0.59	0.65
Rainy of growing season (Mar+Apr+May+Jun)	0.39	0.15	0.76*	0.46	0.33
Winter Rainfall (Jan+Feb+Mar	0.36	0.22	0.02	0.65	0.47
Fall Rainfall (Oct+Nov+Dec)	0.57	0.44	0.21	0.59	0.58
Rainy of growing season+ Previous Rainfall	0.83*	0.76*	0.53	0.75*	0.88*
Annual Rainfall	0.65*	0.38	0.59	0.64*	0.66*

Results of regression equations are shown in Table 5. According to the regression analysis, 83% of annual production of *Artemisia sieberi* could be explained by the last year's rainfall. Production of *Scariola orientalis:* The rainfall of January and May entered to final regression equations (Table 5). Production of *Stipa atriseta* was mainly correlated with rainfall in October and growing rainfall. However, the highest regression coefficient was found for growing rainfall (R^2=0.76). A correlation was found between the production of *Stachys inflate* and the rainfall of October, total annual rainfall and the last year's rainfall.

According to results, for total annual production, the correlation with December and annual rainfall was significant. But in regression analysis, the highest regression coefficient was found between total production previous precipitation (rainfall of growing season + rainfall of years ago) (R^2=0.88).

Table 5. Regression equation and annual total forage yield (Y) as independent variable and rainfall (mm) of individual months and combination of several months of growing season in the Bid Alam site

Specious Production (kg/Year)	Regression equation	r^2
Artemisia sieberi	$Y = 384.048P_{previos} - 3.34$	0.83
	$Y = 275.27P_{Sep} - 3727.3$	0.76
	$Y = 347.29P_{Dec} - 2.77$	0.73
	$Y = 416.61P_{previos} - 14.02$	0.76
Scariola orientalis	$Y = 48.9P_{May} + 0.33$	0.64
	$Y = 76.91P_{Jan} - 0.89$	0.68
Stipa atriseta	$Y = 7.24P_{growing} + 0.04$	0.76
	$Y = 6.37P_{Oct} + 3.17$	0.61
Stachys inflata	$Y = 112.82P_{previos} - 0.38$	0.75
	$Y = 93.40P_{Oct} + 0.432$	0.65
	$Y = 46.08P_{Annual} + 131$	0.64
Total forage yield	$Y = 553.70P_{previos} - 5.11$	0.88
	$Y = 505.51P_{Dec} - 4.53$	0.78
	$Y = 653.6P_{Annual} - 24.54$	0.66

Discussion

The result of the study revealed that increasing the length of the precipitation period improved the relationship between precipitation and annual forage yield. Precipitation pattern had more strong impact on the variations of annual production, and various periods of precipitation had different effects on annual yield of species. The inclusion of various periods of precipitation improved the relationship when correlated with forage production. Results of this research showed that precipitation of past year in addition to precipitation of growing season had the greatest impact on forage production in the Bid Alam site of Abadeh. The reason for a high correlation between the production of *Artemisia sieberi*, *Scariola orientalis*, *Stipa atriseta and Stachys inflata* and total production is expressed that the mentioned species and most species found in the study site were shrubs with deep roots. Therefore, not only precipitation in the same year, but precipitation in the previous year is able to be absorbed by their roots. It has been shown in the study area that rainfall shortage is a limiting factor for growth and forage production, and also dry periods reduce the production of fodder. This result is in agreement with the findings reported by Mirzaali (2011) and Fakhimi (2014). Abdollahi *et al.* (2011) found that precipitation of previous season had an impact on rangeland production. Ehsani *et* *al.* (2007) reported that precipitation indicator in growing season and previous season has the greatest impact on production in an arid site because in winter, the temperature is low and limits the growth of the species. So, plants are not able to use the winter precipitation but moisture reserve in soil and plants uses it in the beginning of growth period. In addition, the results showed that *Stipa atriseta* had a robust correlation with growing season rainfall. Because the roots of this grass penetrate up to 30 cm of soil depth and can use the moisture saturated in this depth. Therefore, much more rainfall outside of the growing season has no effect on plant growth. Studies done by Abdollahi *et al.* (2011), Fakhimi, (2014) & Fakhar Izadi *et al.* (2019) confirm the results of this research.

Conclusion

In such a research, the use of monthly and annual data analysis for independent variables (precipitation) leads to better conclusions and the reason could be attributed to the plant species using the moisture available in soil from previous precipitations. Climate data help landholders to predict long-term range production to calculate long-term grazing capacity. In addition, soil properties and plant life form need to be taken into account. Our results clearly showed that the study model could be used as a logical equation to predict the rangeland forage yield using climate data. Our results clearly showed that regression analysis could help to predict yield data from climatic data.

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چکیده. بررسی تولید علوفه در مرتع برای مدیریت کارآمد و مؤثر مراتع ضروری است. به همین منظور مقادیر تولید علوفه سالانه ۴ گونه مرتعی *Artemisia sieberi, Scariola orientalis, Stipa atriseta, Stachys inflate*، در سایت بیداعلم آباده طی سال‌های ۱۳۷۷- ۱۳۸۶ به مدت ۱۰ سال و سپس طی سال-های ۱۳۹۵-۱۳۹۶ به مدت ۲ سال جمعا به مدت ۱۲ سال به روش قطع و توزین در داخل ۶۰ پلات تصادفی ۲ متر مربعی در طول ۴ تراسکت ۳۰۰ متری اندازه‌گیری شد. آمار پارامترهای اقلیمی نظیر بارندگی، دما، رطوبت نسبی و ساعت آفتابی در این فاصله زمانی نیز از ایستگاه هواشناسی آباده اخذ و برای بررسی روابط بین آن‌ها و تولید در دوره‌های مختلف رشد استفاده شد. میزان تولید علوفه خشک سالانه هر گونه به عنوان متغیر وابسته و میزان بارندگی، دما، رطوبت نسبی و ساعات آفتابی شده به عنوان متغیرهای مستقل در نظر گرفته شدند و روابط بین آن‌ها با استفاده از برنامه رگرسیون چند متغیره خطی برازش داده شد. نتایج نشان داد که بارندگی سال قبل (بارندگی فصل رویش+ بارندگی سال قبل) بیشترین تاثیر را در تولید علوفه سالانه مراتع بید اعلم داشته است. بطوری که ۸۸ درصد تغییرات تولید سالانه را می‌توان با بارندگی سال قبل برآورد کرد. بر اساس نتایج این پژوهش با در اختیار داشتن پارامترهای اقلیمی بویژه بارندگی در دوره‌های مختلف بارش، می‌توان تولید علوفه سالانه گونه‌های شاخص و تولید سالانه سال‌های آتی با دقت بالا قابل برآورد نمود.

کلمات کلیدی: بارندگی، دما، تولید علوفه، مراتع استپی