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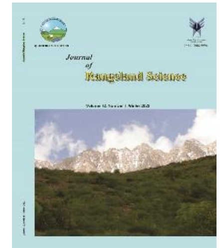
Journal homepage: www.rangeland.ir



Research and Full Length Article:

Evaluation of Meteorological Factors in Estimating Forage Production in Steppe and Semi-steppe Rangelands of Iran

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Received on: 14/07/2020 Accepted on: 12/05/2021
DOI: 10.30495/RS.2022.681732
DOR: 20.1001.1.20089996.2021.12.1.5.0

Abstract. Rangeland production is especially important in meeting food requirement of rangeland societies. Sometimes, historical data are required for long-term grazing capacity estimation. Regression equations that are reasonably reliable for predicting forage production from precipitation characteristics have been developed for rangeland yield estimation. In this research, the relationship between forage production and meteorological factors was evaluated with six-year data for Pashaylogh and Incheboron rangelands (2003 to 2007 and 2017- Golestan province, Iran) and eleven-year data for Nemati rangeland (1998 to 2007 and 2017- Markazi province, Iran). For sampling, four parallel transects with a length of 300 m and at a distance of 100 m from each other were established in the steppe area (Nemati) and six 200-m transects were created in the semi-steppe area (Pashaylogh and Incheboron) and they were located parallel and at a distance of 100 m from each other. Due to the need for uniformity in the data of the rangelands of different provinces and their comparison, plot size of 1×2 m was selected in steppe site, and 1×1 m for semi-steppe sites. Data analysis was done through regression models. The results showed that forage production was related to temperature and precipitation rather than other meteorological factors (temperature, precipitation, sunlight hours, relative humidity, evapotranspiration and average wind speed). The best equation that can predict the relationship between meteorological data and forage production was August precipitation and temperature (R^2=0.88) in Pashaylogh, the precipitation of June (R^2=0.88) in Incheboron rangelands. There was a relationship between forage production (R^2=0.79) with precipitation and temperature in July and in Nemati rangeland. The forage production index was determined based on effective meteorological factors and The Standardized Precipitation-Evapotranspiration (SPEI) drought index. According to meteorological data, a coefficient could be obtained to estimate long-term rangeland production and prevent from forage loss.

Key words: Regression equation, Steppe and semi-steppe rangelands, Rangeland capacity, Meteorological data

Introduction

One of the basic requirements for determining the long-term grazing capacity of rangelands is to know the long-term production of rangelands. For this purpose, it is necessary to monitor and measure forage production during a reasonable statistical period in terms of recurrence of weather events. That is the period in which normal droughts and wet climatic years occurred in the region. The duration of this period is usually recommended to be 10 years for the country's climatic conditions, and it is assumed that during this 10-year period, normal drought and wet years occur in terms of rainfall; otherwise, a longer period can be considered (Ghorbani *et al.*, 2017; Kheradmand., 2017). Gathering such data is usually time consuming and costly. Therefore, it is necessary to estimate the amount of annual rangeland production indirectly and using climate information, and based on the results, long-term rangeland production can be predicted. Studies also show that the value of determinants, and meteorological information are not the same in terms of modeling and forecasting the amount of rangeland production. Different results have been reported depending on the type of weather data as well as the type of vegetation and even the timing of vegetation sampling. What is certain in all studies is that the amount of rangeland forage production can be predicted and modeled based on weather information (Omidvar *et al.*, 2020).

In the other way, recent reports project climate change will affect all rangeland ecosystems, but the greatest impacts will likely occur in semiarid and arid areas (Polley *et al.*, 2013; IPCC, 2014; Havstad *et al.*, 2016; USGCRP, 2018). Rangelands account for roughly 70% of the world's land area and 16% of global food production (Holechek, 2013). Rangeland livestock production is especially important in meeting food needs of pastoral societies across Africa, central Asia, and many parts of South America (Holechek, 2013; Holechek *et al.*, 2017; WRI, 2018).

The relationship between climatic factors spatially rainfall and forage production had been studied by researchers. Regression equations that are reasonably reliable for predicting forage production from precipitation characteristics and climatic factors have developed for some rangeland communities including perennial grass (Kbumalo and Holechek, 2005). Yang *et al.* (2008) determined the relationship between precipitation and global grass production. There are some published data that examined the relationship between climate factors and production (Hurtado-Uria *et al.*, 2014; bayat *et al.*, 2016; Ehsani *et al.*, 2007; Akbarzadeh *et al.*, 2007; Pfeiffer *et al.*, 2019; Hui *et al.*, 2018; Sawalhah *et al.*, 2019; Yalcin, 2018; Omidvar *et al.*, 2020).

On loamy blue grama rangeland in central New Mexico, Pieper *et al.* (1971) found that total herbage production was significantly correlated (R^2= 0.71) with a total annual growing season (June–September) precipitation. On the Santa Rita Range in south central Arizona, Cable and Martin (1975) found that August precipitation was most highly correlated with annual perennial grass production (R^2= 0.63). Akbarzadeh *et al.* (2007) emphasized the effective role of the growing season rainfall in grass forage production in the same area of Polur grassland, Iran.

Ehsani *et al.* (2007) investigated the effect of climate factors on forage production over an eight- year period in Akhtarabad Rangelands located in Saveh region of Iran. Their result showed that the growing season rainfall plus the previous growing year rainfall was the most effective factor in forage production. Their results also showed that the estimation of forage production in *Bromus tomentellus* and *Agropyron trichophorum* community based on the proposed equations had no significant correlation for the long-term period.

Wight *et al.* (1984) developed a rangeland production model (ERHYM) for estimation of biomass production in relation to climatic parameters and soil water to plant growth. They used information of soil moisture at the beginning of the growing season, daily precipitation statistics, average air temperature and light as a production index. This model was used by other researchers (Kizito *et al.*, 2007; Krauss *et al.*, 2007; Chavula and Gommes, 2006; Ehsani *et al.*, (2007).

Holechek *et al.* (2004) also stated that observing the entry of an appropriate number of livestock into the rangeland is the most important part of successful rangeland management. Therefore, if the criteria for measuring grazing capacity are problematic and some cases are ignored, the grazing capacity is not calculated correctly and the livestock feeding programs in the rangeland do not have the desired performance and the livestock balance in the rangeland will not be established.

In this regard, this study aimed to investigate the relationship between meteorological factors and rangeland production to develop a predictive model for calculating long-term gazing capacity of period that we had data in each rangeland and suggest its application in the same areas.

Materials and Methods

Study Areas

Studied rangelands are located in Golestan province (Pashaylogh and Incheboron) and Markazi (Nemati) of Iran. These rangelands were selected from "Rangeland Assessment of the different climatic zone project in Research Institute of Forests and Rangelands of Iran" which has been done by (Arzani, 2009). The characteristics of studied rangelands shown in Tables 1, 2 and 3 include precipitation, soil characteristics and vegetation condition in three rangelands.

Table 1. Physical characteristics of the study sites (Arzani, 2009)

Sits characteristics	Rangeland Name		
	Nemati	Pashaylogh	Incheboron
Dominant vegetation type	*Artemisia sieberi-Salsola laricina*	*Salsola arbusculiformis—Artemisia sieberi*	*Halocnemum strobilaceum*
Dominant slope %	20%	20%	1 to 2%
Dominant aspect	Southeast	East and West- West and East	North
Average altitude	1325 m	150-430 m	10 m
Soil type	Fan-shaped debris	Hills	Alluvial
Soil texture	Sandy clay loam	Silt loam	silt loam
Long term, annual rainfall	200 mm	360 mm	300 mm
Long term, annual temperature	18.2◦C	17.7◦C	17.8◦C
Climate class	Dry cold desert	Semi-dry to dry	Semi-desert

Table 2. Information on soil surface cover and condition and trend of the studied rangelands (Arzani, 2009)

Rangeland Name	Years	Crown Cover (%)	Litter (%)	Stones and Pebbles (%)	Bare soil (%)	Total min=3, max=50	Rangeland Condition	Rangeland Trend
Nemati	1998	21.3	4.5	54.2	17.6	30.5	Medium	-
	1999	22.4	4.2	52.1	21.2	29.6	Weak	Stable
	2000	22.8	2.0	54.3	20.9	23	Weak	Stable
	2001	26.1	4.1	65.9	3.8	25.5	Weak	Stable
	2002	23.8	3.5	51.4	21.4	31.4	Medium	Positive
	2003	23.7	4.7	52.0	17.9	28.1	Weak	Positive
	2004	25.2	4.7	52.1	17.9	26.6	Weak	Positive
	2005	25.4	3.4	51.3	21.4	23.2	Weak	Positive
	2006	24.8	5.3	51.9	17.9	19	Very Weak	Positive
	2007	24.3	4.2	52.1	19.4	24.5	Weak	Positive
	2017	23.0	4.3	52	17.2	31.5	Medium	Positive
Pashaylogh	2003	41.2	6.2	27.3	22.7	21.3	Weak	-
	2004	30.7	5.8	39.7	21.6	6.2	Weak	Stable
	2005	37.1	6.2	27.2	27.8	25.0	Weak	Stable
	2006	24.0	6.4	35.6	32.0	23.5	Weak	Stable
	2007	19.5	3.5	39.6	36.9	22.2	Weak	Stable
	2017	23.2	3.5	35	30	25.3	Weak	Negative
Incheboron	2003	61.2	2.8	0.0	35.1	32.2	Medium	-
	2004	46.2	13	0.0	42.4	21.0	Weak	Negative
	2005	28.8	4.1	0.0	66.8	24.8	Weak	Stable
	2006	27.3	3.4	0.0	69.6	26.5	Weak	Stable
	2007	32.6	4.4	0.0	62.0	23.3	Weak	Stable
	2017	47.6	4.3	0.0	35.0	25.6	Weak	Stable

Table 3. Monthly and total annual precipitation in the different years in the studied rangelands

Rangeland Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Precipitation (mm)
Pashaylogh	2003	15.2	58.3	80.7	81.3	34.2	30.4	1.6	0.8	0.7	16.7	57.0	37.3	414.4
	2004	29.9	12.0	63.5	92.5	18.9	6.6	53.1	1.0	56.0	30.7	74.3	34.7	473.0
	2005	76.7	57.6	50.0	13.5	36.1	19.0	39.0	23.0	0.1	30.2	45.0	29.1	419.5
	2006	28.8	23.9	43.9	34.3	24.2	3.5	0.2	0.0	14.2	40.7	51.3	41.0	306.0
	2007	8.5	26.8	123.6	43.9	16.8	79.5	2.4	0.8	43.2	1.6	35.2	46.8	429.2
	2017	31.1	45.3	30.3	39.5	0.0	0.0	5.3	2.0	5.6	16.6	7.4	25.5	208.7
Incheboron	2003	12.0	62.7	112.2	57.0	51.3	54.2	6.1	33.4	5.0	47.1	133.5	56.8	631.4
	2004	51.2	10.7	79.0	78.3	30.7	28.3	63.7	1.6	28.7	41.5	106.0	74.6	594.3
	2005	99.6	49.2	81.4	35.2	63.5	18.9	0.1	14.5	36.7	20.2	121.1	139.0	679.5
	2006	61.8	16.5	41.9	37.8	29.6	9.7	3.7	0.0	10.9	39.0	110.4	56.8	418.2
	2007	25.5	42.4	99.6	26.0	30.6	19.0	2.7	20.1	29.3	0.1	51.0	37.1	383.5
	2017	49.3	27.7	33.13	53.4	5.2	0.3	8.0	0	72.3	46.2	68.2	21.0	384.9
Nemati	1998	45.8	18.9	50.9	33.9	14.6	0.2	0.9	2.2	0.2	12.1	1.2	13.4	194
	1999	52.6	20.6	25.4	3.5	2.6	0.0	7.6	0.0	0.0	13.4	45.6	16.8	188
	2000	33.1	20.0	5.4	6.6	1.0	0.0	0.0	0.0	2.0	24.4	32.4	114.3	239
	2001	27.1	16.0	20.5	0.0	24.1	4.1	1.0	0.9	2.1	1.1	12.6	63.3	173
	2002	34.7	2.6	5.6	41.8	5.7	0.0	0.0	0.0	0.0	0.5	18.1	31.3	140
	2003	29.9	32.4	46.41	59.8	9.3	0.0	0.0	0.0	0.0	1.6	16.6	54.8	251
	2004	88.4	4.2	14.1	31.5	37.3	0.0	7.0	0.0	0.0	2.0	44.7	32.4	262
	2005	53.2	27.7	52.2	19.5	6.8	0.0	0.0	0.1	0.0	0.9	42.6	10	213
	2006	59.1	28.1	18.6	28.2	6.7	0.0	0.0	0.0	0.0	19.5	15.4	35.9	212
	2007	12.5	27.2	47.0	54.0	17.2	1.0	12.0	0.0	0.0	0.5	15.1	33.0	219
	2017	7.5	10.2	19.0	18.0	22.7	30.0	35.2	33.0	27.3	19.7	10.9	8.6	242

Research Methodology

Weather data were collected from the Maraveh Tappeh (for Pashaylogh rangeland), Gorgan (Incheboron rangeland) and Saveh (for Nemati rangeland) synoptic stations..

The main species in studied rangelands has been shown in Table 4. In order to sample, four parallel transects with a length of 300 m and at a distance of 100 m from each other were established in the steppe area (Nemati) and six 200-m transects were created in the semi-steppe area (Pashaylogh and Incheboron) which are located parallel and at a distance of 100 m from each other. Due to the need for uniformity in the data of the rangelands of different provinces and their comparison, plot size in steppe site was 1×2 m and in semi-steppe sites, it was 1×1 m due to life form and vegetation distribution.

Plotting in each transect was done in such a way that while the distances of the plots were the same, the principle of randomness was also observed, and therefore, the starting point of the transects was not the same. The number of plots dropped in each transect was 15, which were placed at a distance of about 28 m from each other. Therefore, the total number of plots dropped on each site was 60.

Vegetation cover was estimated in studied years, 15 plots were clipped, air-dried and weighed. Forage production was determined based on regression equation between weighted samples and vegetation cover (Arzani and Abedi, 2013). Climatic factors studied in this study include precipitation (monthly, annual, total precipitation from July to September, previous July to September, growing season (March to June), previous March to June, January or June, previous January to June and May to September) (Table 5).

The long-term measured forage production was considered as the dependent variable and the mentioned meteorological parameters were considered as the independent parameters.

Data analysis was done in SPSS software through linear regression and Stepwise model. The suitable models were obtained to predict forage production in studied rangelands.

To test the obtained equations, due to the fact that the test data should not be shared with the model training data, the data of one transect were not used in model training but they were used to test the accuracy of the equations (Kbumalo and Holechek, 2005).

Finally, according to the results of analysis and long-term production data, a coefficient was proposed. The coefficient can be applied to adjust the one-year production measurement in a way that rangeland managers do not face to loss or shortage of forage. We recommend the coefficient be used for a period of ten years to be sure that variation occurred in this period.

Table 4. Vegetation species in Pashaylogh, Incheboron and Nemati rangelands

Rangeland	Name and palatability class		
	I	II	III
Pashaylogh	Annual forbs *Astragalus podolobus*	Annual grasses *Artemisia sieberi* *Cynodon dactylon* *Salsola arbusculiformis*	*Salsola tomentosa*
Incheboron	Annual forbs	*Halocnemum strobilaceum*	*Aeluropus lagopoides*
Nemati		*Salsola laricina* *Artemisia sieberi*	*Stipa barbata* Annual grasses

Noaea mucronata

Table5. Combined precipitation (mm) in three studied rangeland

Sites	Year	Annual Precipitation	July–Sept	Previous Jul–Sept	Growing Season (Mar-June)	Previous Season (Mar–Jun)	Jan-June	Previous Jan-June	May-Sept
Pashaylogh	2003	414.3	3.1	57.9	226.7	129	300.2	212.1	67.8
	2004	473.0	110.0	3.1	181.4	226.7	223.3	300.2	135.5
	2005	419.4	62.1	110.0	118.6	181.4	252.9	223.3	117.3
	2006	306.0	14.4	62.1	105.9	118.6	158.5	252.9	42.1
	2007	429.2	46.4	14.4	263.8	105.9	299.1	158.5	142.7
	2017	208.7	12.9	34.5	69.8	162.9	146.2	252.9	12.9
Incheboron	2003	631.4	44.5	57.4	274.6	240.0	349.3	322.9	149.9
	2004	594.2	94	44.5	216.2	274.6	278.1	349.3	153.0
	2005	679.4	51.2	93.9	198.9	216.2	347.7	278.1	133.6
	2006	418.2	14.6	51.2	118.9	198.9	197.2	347.7	53.9
	2007	383.4	52.1	14.6	175.2	118.9	243.1	197.2	101.7
	2017	384.9	80.3	98.9	92.1	220.6	169.1	375.5	85.8
Nemati	1998	194.3	3.3	1.0	99.6	60.3	164.3	64.4	18.1
	1999	188.0	7.6	3.3	31.5	99.6	104.6	164.3	10.2
	2000	239.2	2.0	7.6	13.0	31.5	66.1	104.6	3.0
	2001	172.8	4.0	2.0	48.7	13	91.8	66.1	32.2
	2002	140.3	0.0	4.0	53.1	48.7	90.4	91.8	5.7
	2003	250.8	0.0	0.0	115.5	53.1	177.8	90.4	9.3
	2004	261.6	7.0	0.0	82.9	115.5	175.5	177.8	44.3
	2005	213.0	0.1	7.0	78.5	82.9	159.4	175.5	6.9
	2006	211.5	0.0	0.1	53.5	78.5	140.7	159.4	6.7
	2007	219.5	12.0	0.0	119.2	53.5	158.9	140.7	30.2
	2017	167.7	12.3	0.0	97.0	44.7	151.2	75.4	33.5

Results

The average of forage production in Pashaylogh, Incheboron (6 years) was 479 and 310 kg/ha respectively, and it was 214 kg/ha in Nemati rangelands (average of 11 years).

The results of simple and multiple linear regressions are shown in Table 6 and the results of the stepwise regression are shown in Table 7.

It is noticeable that there were no forage production data collected between 2007 and 2017 in the studied rangelands. Therefore, meteorological data have been omitted for years without forage production data. All models were tested for all rangelands, but the non-significance equations were not given in Tables 6 and 7.

The average wind speed in July (R^2=0.88) in Incheboron rangeland had been one of the factors affecting production. The amount of wind speed had been effective on production in fall (R^2=0.88), November (R^2=0.91) and September (R^2=0.70) in Pashaylogh rangeland.

The total annual sunlight hours (R^2=0.75) and total winter sunlight hours (R^2=0.85) were inversely related to the amount of production in incheboron rangeland, the total number of sunlight hours in August (R^2=0.74) was inversely related to the forage production in Pashaylogh rangeland.

The minimum temperature in May (R^2=0.79) and the maximum temperature in spring (R^2=0.78) and June (R^2=0.70) were inversely related to production in Incheboron rangeland in shrub vegetation community. The increase in the maximum temperature in September (R^2=0.77) has also led to a decrease in production in Pashaylogh rangeland. Growing season precipitation had a correlation (R^2=0.78) with plant production while June precipitation showed (R^2=0.88) and multiple linear regression June precipitation and growing season precipitation (R^2=0.88) in Incheboron rangeland have an effective and positive relationship with forage production (Table 6).

Multiple linear regression of August temperature and precipitation (R^2=0.87) had also a significant correlation with forage production. The temperature and precipitation in July had a significant relationship with forage production in Nemati rangeland (R^2=0.63).The relative humidity had a significant relationship with the amount of production in Pashaylogh rangeland in September (R^2=0.67) and August (R^2=0.81). Moreover, the stepwise regression analysis was used to find the most important variables affecting forage production (Table 6).

The appropriate model for production forecast (stepwise multiple regression) in each of the three studied rangelands is given in Table 7. Accordingly, the August precipitation (R^2=0.98) was the most effective parameter in Pashaylogh rangeland. The June precipitation was a key factor in Incheboron rangeland (R^2=0.88). The temperature and precipitation in July had been evaluated as the most important factors in Nemati rangelands (R^2=0.79) (Table 7).

Table 6. The regression equations with acceptable response in studied rangelands (simple linear and multiple simple linear regressions)

Rangeland	Meteorological Factor	Regression Equations	R^2	Sig.
Incheboron	July average wind speed (m/s)	Y = -138.3 X + 706.8	0.80	0.01
	Yearly total hours of sunlight (Hour)	Y = -037 X + 1146.3	0.75	0.02
	Winter total hours of sunlight (Hour)	Y = -1.2 X + 839.9	0.85	0.00
	May Minimum temperature (° C)	Y = -18.2 X + 486.9	0.79	0.01
	Spring, Maximum temperature (° C)	Y = -70.1 X + 3006.2	0.78	0.02
	June Maximum temperature (° C)	Y = -32.4 X + 1515.3	0.70	0.03
	Total evapotranspiration (Fall)	Y = 5.23 X – 560.08	0.82	0.01
	June precipitation (mm)	Y= 3.8 X + 226.9	0.88	0.00
	Growth season precipitation	Y = 1.007 + 129.4	0.78	0.01
	X1 =June precipitation X2 =Growth season precipitation	Y = 4.2 X1 – 0.11 X2 + 238.8	0.88	0.04
Pashaylogh	Fall average wind speed (m/s)	Y = -87.3 X + 1012.8	0.88	0.00
	November average wind speed (m/s)	-141.7 X + 821.2	0.91	0.00
	September average wind speed (m/s)	-141.2 X + 954.1	0.70	0.03
	August total hours of sunshine (Hour)	Y = -5.6 X + 2400.5	0.74	0.02
	September relative humidity (%)	Y = 15.9 X – 290.7	0.67	0.04
	August relative humidity (%)	Y = 17.2 X – 272.6	0.81	0.01
	Sept Maximum temperature (°C)	Y = -54.2 X + 2604.1	0.77	0.02
	X1 = August precipitation, X2 = August temperature	Y = 1.95 X1 – 67.07 X2 +2444.2	0.87	0.04
	X1 = August precipitation, X2 = Spring relative humidity	Y = 4.6X1 – 18.3X2 + 3638.3	0.98	0.00
	August temperature (° C)	Y = -77.03X + 2746.4	0.85	0.00
Nemati	X1 = July precipitation, X2 = July temperature	Y = 9.2X1 + 12.95X2 -245.07	0.63	0.01

Table 7. Regression models to forecasting forage production in Pashaylogh, Incheboron and Nemati rangelands using stepwise regression

Rangelands	Parameters	Predictive equations	R^2	Sig.
Incheboron	X= June precipitation	Y = 3.82 X + 226.95	0.98	0.00
Pashaylogh	X1= August precipitation X2 = August temperature	Y = 1.95 X1 – 67.07 X2 + 2444.2	0.88	0.00
Nemati	X1 = July temperature X1= July precipitation	Y = 12.96 X1 + 9.17 X2 – 245.07	0.79	0.00

Appropriate coefficient for calculating long-term production

According to the regression analysis between production and meteorological factors, the precipitation and temperature were the most effective factors in forage production.

The SPEI drought index was applied to determine drought. SPEI takes into account the temperature and precipitation in determining the coefficient of drought. In the selected years, there were normal drought and wet years in the regions (Table 8).

Expected productions in the years were arranged in descending order to find base year for calculating long-term production. The base year production selection must be suitable for 70% of studied years. According to the production of the base year in each rangeland, a coefficient was selected by measuring the production of one year as a good average, it is possible to use the obtained coefficient to consider the production that does not harm the rangeland in drought years and does not lead to the accumulation of forage in wet years. This coefficients were 0.65, 0.65 and 0.50 for Pashaylogh, Incheboron and Nemati rangelands, respectively.

Table 8. Information needed to coefficient calculation rangelands (Arzani, 2009) and present study data collection

Site	Year	Precipitation (mm)	Production (kg/ha)	SPEI index
Pashaylogh	2017	390	208	Mild Drought
	2007	392	429	Normal
	2006	393	306	Normal
	2004	506	437	Normal
	2003	556	414	Mild Wet
	2005	640	419	Mild Wet
Incheboron	2017	384	240	Normal
	2007	383	247	Mild Drought
	2006	418	275	Normal
	2005	679	311	Mild Wet
	2004	594	347	Normal
	2003	631	440	Normal
Nemati	1998	194	144	Normal
	2002	140	150	Normal
	2000	239	170	Mild Drought
	1999	188	180	Normal
	2005	213	191	Normal
	2003	250	201	Normal
	2004	261	221	Mild Wet
	2001	172	229	Normal
	2006	211	234	Normal
	2017	167	310	Normal
	2007	219	330	Normal

Discussion

The relationship between the studied parameters was investigated using simple and multiple linear regression, and the following results were obtained:

In this research, the equation of wind speed was significant, it has an inverse relationship with the forage production. In general, increasing the average wind speed reduces the available water of the plant and has a significant inverse effect on forage production. Aauenroth (1992) and Gomara *et al.* (2020) have stated that the wind speed coupled with the temperature will lead to a decrease in humidity by increasing evapotranspiration.

In Incheboron rangeland, the total annual sunlight hours and total winter sunlight hours were inversely related to the amount of production. In Pashaylogh rangeland, the total number of sunlight hours in August was inversely related to the forage production. The research of Gomaro *et al.* (2020) confirms our results. The cause of this relationship back to an increase in evapotranspiration with increase in sunlight hours.

The minimum and maximum temperature was inversely related to production in Incheboron and Pashaylogh rangelands. The minimum and maximum temperatures have prevented the plant from fully benefiting from seasonal rains due to its effect on unsuitable plant growth conditions (Andales *et al.*, 2006). In this regard, Smart (2005) stated that cold temperatures, especially those below 0°C rupture plant cell walls and damage meristem tissue in plants.

Unlike maximum and minimum temperatures, mean temperatures have a positive effect on forage production. In conclusion, when the temperature is favorable, extended root system can efficiently absorb more moisture from each event of rainfalls (Fakhar Izadi *et al.*, 2019). Growing season precipitation in Incheboron, August Precipitation (end of the growing season) in Pashaylogh and July precipitation (within growing season) in Nemati rangelands had an effective and positive relationship with forage production. However, the rainfall of the growing season is more effective for the growth of herbaceous plants (Akbarzadeh *et al.*, 2007; Kbumalo & Holecheck, 2005, Ehsani *et al.*, 2007).

According to the equation, the amount of precipitation has a positive relationship and the amount of temperature has a negative relationship with forage production, Smart (2005) also found that spring precipitation had a significant effect on forage production.

The temperature and precipitation in July had a significant relationship with forage production in Nemati rangeland (R^2=0.63) dominated by shrub species. Kruse *et al.* (2007) also found a significant relationship between July temperature and precipitation with forage production.

Relative humidity factor also showed a significant relationship with the amount of production in Pashaylogh rangeland so that the increase in relative humidity in August and September has been effective in increasing in forage production (Omidvar *et al.*, 2020; Gomaro *et al.*, 2020).

The results obtained from the stepwise regression show that the best equation that can predict the relationship between meteorological data and forage production was August precipitation and temperature (R^2=0.88) at Pashaylogh with domination of shrub species (*Salsola arbusculiformis* and *Artemisia sieberi*) and precipitation of June (R^2=0.88) with dominance of *Halocnemum* *strobilaceum* (shrub species). There was a relationship between forage production (R^2=0.79) with precipitation and temperature in July and in Nemati rangeland with dominated species of *Artemisia sieberi* and *Salsola laricina*. As the results showed, it is possible to use meteorological data for prediction of rangeland forage production. So, it is good to use this fact to help government agency to measure one year production and to lood what has been happened in 10 years past of his measurement in meteorological data to adjust current year measurement to a year condition suitable for grazing capacity calculation because this research investigated to find a regression coefficient that can be used to adjust the production measured with one-year data to at least for a period of 10 years past. In this regard, meteorological data (temperature, precipitation, sunlight hours, relative humidity, evapotranspiration as well as average wind speed) and SPEI drought index (determination of normal, drought and wet years) had been used to determine the coefficient.

Others also attempt to provide models for estimating the biomass production of herbaceous plants from climatic data. Wisiol (1984) states that the amount of forage production due to excess rainfall can be predicted according to regression analysis in the presence of long-term production statistics and climate.

Arzani and King (1994) examined the long-term rangeland capacity for a region in Western Australia. He estimates forage production of 23 years by meteorological data. The results of his study showed that long-term rangeland production could be estimated using the performance obtained from field measurements and using historical climate data. Cable and Martin (1975) also found that August precipitation was most highly correlated with annual, perennial production (R^2= 0.63) in the perennial grass community.

Generally, the coefficients obtained in this research help managers to predict historical forage production to calculate long-term grazing capacity for sustainable grazing management. In this regard, it is necessary to evaluate this work in other regions and develop a model for prediction and estimation of forage production suitable for long term grazing capacity estimation.

Acknowledgment

The authors gratefully acknowledge the financial support for this work that was provided by University of Tehran Science & Technology Park, Tehran, Iran.

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ارزیابی عوامل اقلیمی در تخمین تولید علوفه در مراتع استپی و نیمه‌استپی

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چکیده. در اندازه‌گیری تولید گیاهی روش‌های متعارف مخرب و وقت‌گیر هستند. در مواردی استفاده از داده-های طولانی‌مدت برای پیش‌بینی میزان تولید گیاهی مورد نیاز هستند. استفاده از معادلات رگرسیونی بر اساس خصوصیات بارندگی برای پیش‌بینی تولید گیاهی مراتع توسعه پیدا کرده است. در این تحقیق رابطه بین تولید علوفه و مشخصات هواشناسی در سه مرتع پاشایلق و اینچه‌برون با ۶ سال داده تولید اندازه‌گیری شده (۱۳۸۲ تا ۱۳۸۶ و ۱۳۹۶ در استان گلستان) و مرتع نعمتی با ۱۱ سال داده (۱۳۷۷ تا ۱۳۸۶ و ۱۳۹۶ در استان مرکزی)، بررسی شده است. برای نمونه‌برداری، در منطقه استپی (نعمتی) چهار ترانسکت موازی به طول ۳۰۰ متر و به فواصل ۱۰۰ متر از یکدیگر و در منطقه نیمه‌استپی (پاشایلق و اینچه برون) ۶ ترانسکت ۲۰۰ متری که به طور موازی و به فاصله ۱۰۰ متر از یکدیگر ایجاد شدند. به دلیل لزوم یکنواختی در داده‌های مراتع استان‌های مختلف و مقایسه آنها باهم اندازه پلات در سایت‌های استپی یکسان و با ابعاد ۱×۲ متر و در سایت‌های نیمه‌استپی ۱×۱ متر انتخاب شدند. بررسی همبستگی بین داده‌های اقلیمی و تولید مرتع از طریق معادلات رگرسیون انجام شد. نتایج نشان داد که از بین عوامل هواشناسی مورد استفاده در تحقیق (بارندگی، دما، ساعات آفتابی، رطوبت نسبی، سرعت باد و تبخیر و تعرق)، بارندگی و دما در پیش‌بینی تولید تأثیر معنی‌داری داشتند. بهترین معادلات پیش‌بینی‌کننده تولید علوفه دما و بارندگی مرداد (R^2= ۰/۸۸) در پاشایلق، بارندگی ماه خرداد (R^2= ۰/۸۸) در اینچه‌برون و دما و بارندگی تیر (R^2= ۰/۷۹) در مرتع نعمتی بودند. ضریب تولید علوفه بر اساس داده‌های هواشناسی و شاخص خشکسالی بارندگی و تبخیر و تعرق استانداردشده (SPEI) محاسبه شد. با استفاده از داده‌های هواشناسی، می‌توان به ضریب مطمئنی برای برآورد تولید بلندمدت مرتع در جهت جلوگیری از اتلاف و کمبود علوفه دست یافت.

کلمات کلیدی: معادلات رگرسیونی، مراتع استپی و نیمه‌استپی، ظرفیت چرا، داده‌های هواشناسی