African Journal of Agricultural Research Vol. 6(18), pp. 4223-4229, 12 September, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.891
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Impact of precipitation pattern on forage production in Pashylogh Rangeland, Iran

Abdultaher Mirzaali[1]*, Hossin Arzani[2], Mohammad Jafari[2], Ali Ehsani[3], Jamshid Khatirnamani[4] and Idris Mirzaali[5]

[1]Department of Range Management, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[2]Department of Natural Resources, Tehran University, Tehran, Iran.
[3]Research Institute of Forest and Rangelands, Tehran, Iran.
[4]Research Institute of Forest and Rangelands, Gorgan, Iran.
[5]Department of Agriculture, Gorgan Branch, Islamic Azad University, Gorgan, Iran.

Accepted 2 August, 2011

The responses of four steppe forage species in the Pashylogh rangeland to precipitation timing were assessed for a period of 7 years (2003 to2007 and 2009 to 2010). Regression analysis was used to examine the relationship between annual production and different periods of precipitation. Annual yields of the different steppe forage species responded differently to the periods of precipitation. Precipitation during November to December and April to May gave the highest predictor of total forage production (r^2= 0.80). Annual productivity of *Salsola arbosculoformis* was most closely correlated with precipitation in November to December and April to May (r^2 = 0.86), *Artemisia seiberi* with November to January (r^2 = 0.68), *Salsola tomentosa* in January (r^2 = 0.72) and *Astragalus podolobus* with from the end of the growing season in previous year and the new growing season (r^2 = 0.88). This study supported the use of seasonal period precipitation instead of annual precipitation in effectively estimating the herbage production through a statistical model.

Key words: Precipitation, forage, yield, Pashylogh.

INTRODUCTION

Due to extensive rangeland in Iran, measuring of herbage yield is difficult in each year. Therefore use of indirect methods based on weather data would be useful for anticipating herbage yield (Bagestani and Zare, 2007). Several studies have demonstrated the relationship between weather and climatic fluctuation and forage yield (Duncan and Woodmansee, 1975; Pumphery, 1980; Fetcher and Trlica 1980; Hanson et al., 1982; Wight et al., 1984; Smoliak, 1986; George et al., 1989; Hien, 2006; Bets, et al., 2006 and Ehsani et al., 2007).

Weather variables, especially precipitation in arid and semiarid ecosystems are the principal environmental factors influencing plant growth (George et al., 1989). Composition, function and productivity of rangeland ecosystem are largely driven by yearly fluctuations in abiotic drivers, primarily precipitation. However, other factors, such as high grazing do have influence on the ecosystem (Fynn and O' Connor, 2000; Sullivan and Rohed, 2002). Precipitation pattern has a major influence on herbage production on rangeland (Mclean and Smith, 1973).

The establishment of quantitative relationships between weather variables and forage production has been expressed in regression models such as described by Murphy (1970), Shiflet and Dietz (1974), Duncan and Woodmansee (1975), Fetcher and Trlica(1980), Smoliak (1986), Georg et al. (1989), Khumalo and Holchek (2005), Andales et al. (2006), and Baghestani and Zare, (2007). They explored the relationship between forage production and precipitation and demonstrated a linear equation between forage production and weather

*Corresponding author. E- mail: mirzaali52@yahoo.com. Tel: 0098 171 3351003, 0098 9113715767.

Table 1. Forage yield of major species (kg ha^{-1}) at the Pashylogh site.

Year	*Artemisia seiberi*	*Astragalus podolobus*	*Salsola arbosculoformis*	*Salsola tomentosa*	Total yield
2003	62.4	19.5	266.9	4.4	353.2
2004	105.3	3.3	270.7	59.3	438.7
2005	102.7	15.3	176.7	75.3	370.0
2006	55.4	2.0	153.2	40.0	250.6
2007	60.2	11.3	195.5	16.9	284.0
2009	58.4	8.1	192.5	45.3	304.3
2010	81.7	7.0	210.0	32.0	330.7
Average	75.2	9.5	209.4	39.0	333.1

variables. They suggested that the variations in forage production were more strongly affected by precipitation.

Duncan and Woodmansee (1975) found forage production more closely related to precipitation in April, November and January. George et al. (1989) reported that fall and winter precipitation, winter temperature and winter dry period patterns have been a strong influence on peak standing crop. Willey et al. (1992) found a linear model to estimate forage production from the annual rainfall in Nigeria. Fall and winter precipitation, winter temperature, and winter dry period patterns have a strong influence on peck standing crop (George et.al., 1989). Hansen et al. (1982) demonstrated the previous year precipitation impacted on forage production.

The present investigation focused on the relationships between precipitation and annual forage productions of the native rangeland of Pashylogh, Iran. Our objectives were to improve the predictability of functions relating forage production to precipitation distribution by including various period of precipitation. This paper presents the results of simple correlation, regression and stepwise multiple regression analysis between precipitation pattern and forage production.

Site description

The study site was located on the Pashylogh rangeland in north Maraveh tape, Iran (55° 51 E, 37° 46 N) at elevation of 150 to 430 m. Soils were silty loamy, surface soil no salinity, soil organic mater with less than 0.6%. The climate is semiarid. Average annual precipitation (January through December) 17-year period (1993 to 2009) is 358 mm. Most precipitation occurs as rain in the fall and winter, 70% annual precipitations occur from October through April, 45% annual precipitations occur in the growing season (middle February through late July). Summer is warm and dry, but showers do occur some years. Mean annual temperature and humidity are 17.5° C and 60%, respectively. The principal forage species include *Salsola arbosculoformis, Artemisia seiberi, Salsola tomentosa and Astragalus podolobus.*

METHODS

Weather data were acquired from the Maraveh weather station, about 10 km from the Pashylogh rangeland. Precipitation was summed for months of year, the growing season and the different combinations. The independent variables are listed in Table 1.

Forage production data for four species *Salsola arbosculoformis, Artemisia seiberi, Salsola tomentosa and Astragalus podolobus* were collected from 2003 to 2007 and 2009 to 2010. Sampling was done random – systematic along 6 transects with 200 m length and 100 m distance from each other. During the study period, 60 plots (1m^2) were sampled and 15 plots protected from grazing by the portable cages, were clipped, air-dried and weighed annually (Arzani and Kingh, 1994). The portable cages were randomly distributed in large fields that were grazed by sheep.

Linear regression method was used to investigate the relationships between forage production and precipitation. This model was used in pervious studies (Smoliak, 1986; George et al., 1989; Hien, 2006; Baghestani and Zare, 2007; Ehsani et al., 2007).

A total of 50 variables (independent variables) were used in the analysis. All independent variables and seven years herbage yields were subjected to correlation analysis. Significant variables were regressed with herbage yields. Stepwise multiple regressions were used to investigate the most effective variable and the most appropriate model to estimated herbage yield.

RESULTS

The annual dry weight forage production during study period varied from a low of 250.6 kg ha^{-1} to a high of 438.7 kg ha^{-1} (Table 1).Monthly, two months, three months, four months and growing season precipitation is a Table 2. Correlation between forage production and various period of precipitation at selected period are shown in Table 3. Total forage production was significantly correlated with November to December and April through May precipitation (Table 3). The regression equation derived from the relationship of total forage production and November to December and April through May precipitation is:

$$Y = 0.019\ P_{Nov-Dec+Apr-May} + 2.80 \quad (r^2 = 0.80,\ p = 0.007)$$

Where Y = estimated total forage production (kg ha^{-1}) , P= precipitation (mm).

Herbage yield of *Salsola arbosculoformis* was significantly correlated with precipitation of the months of

Table 2. Mean, minimum (min) and maximum (max) precipitation (mm) and standard deviation (sd) at the Pashylogh site on study period (2003 to 2010).

Month	Mean	Min	Max	Sd
September	15.58	0	55.8	21.67
October	22.33	1.8	45.4	16.50
November	39.95	13.2	74.6	20.69
December	37.89	22.3	50.8	10.02
January	29.60	7.4	75.8	20.66
February	43.34	11.7	73.3	25.14
March	55.35	14.5	122.1	33.43
April	56.30	12.9	96	30.04
May	22.20	10.8	36.1	9.69
June	19.75	1.8	79.6	25.94
July	14.03	0	55.7	21.26
August	6.46	0	25.3	11.06
Annual (September to August)	362.76	242.6	509.8	93.62
October to November [1]	67.51	35.50	105.40	26.23
November to December	83.89	65.80	108.50	15.17
December to January	69.79	46.90	109.70	20.41
January to February	78.13	33.50	134.40	37.35
February to March	108.26	70.90	148.20	29.96
March to April	119.80	62.50	166.60	45.98
April to May	82.44	49.00	116.10	28.32
September to November	77.67	29.60	161.20	44.20
October to December	102.66	47.90	139.30	31.20
November to January	108.46	64.60	184.30	38.71
December to February	114.77	73.00	168.30	37.82
January to March	139.31	98.50	184.00	30.53
February to April	166.87	105.00	220.90	44.08
March to May	143.63	98.40	196.60	42.33
April to June	103.94	60.40	146.20	33.44
September to December	114.31	51.90	195.10	45.59
October to January	133.71	77.00	215.10	41.72
November to February	155.53	122.20	242.90	43.95
December to March	175.96	125.60	217.90	33.91
January to April	197.93	132.60	239.30	35.51
February to May	190.70	127.20	254.40	42.24
March to June	165.13	102.50	262.60	60.69
October to December + February	149.73	121.10	197.90	29.34
October to December + March	163.84	93.70	253.70	55.05
October to December + April	161.27	128.00	206.60	31.71
October to December + May	126.49	60.00	175.40	36.55
October to December + March to April	222.46	159.40	298.20	56.46
October to December + April to May	185.10	150.20	229.10	32.89
October to december + February to March	210.91	164.80	279.80	47.14
October to November + April	124.63	84.50	170.50	28.66
October to November + February to March	174.27	136.90	240.30	42.80
October to November + March to April	185.81	112.60	258.70	53.12
October to November + April to May	148.46	113.60	187.90	28.12
Grow season	168.76	116.70	243.30	45.78
EPGS[2] - growing season	395.77	315.50	469.50	58.01
NO-DE+MAR-AP	197.20	142.00	257.50	47.55
NO-DE+AP-MAY	159.84	122.10	207.50	28.24

1.October through November precipitation 2. EPGS: End of previous growing season.

Table 3. Simple correlation coefficients(r) of forage yield with precipitation.

Month	*Artemisia seiberi*	*Astragalus podolobus*	*Salsola arbosculoformis*	*Salsola tomentosa*	Total yield
September	0.51	0.421	-0.383	0.583	0.16
October	-0.295	0.584	0.098	-0.4	-0.149
November	0.715	-0.067	-0.169	0.638	0.32
December	0.138	0.521	0.6	-0.568	0.25
January	0.671	0.092	-0.333	.847*	0.336
February	-0.15	0.418	-0.158	-0.068	-0.105
March	-0.27	0.411	0.226	-0.514	-0.113
April	-0.086	-0.1	0.735	-0.255	0.439
May	0.333	0.601	0.064	0.024	0.178
June	-0.268	0.446	0.004	-0.522	-0.284
September to October	0.078	0.662	-0.328	0.251	-0.036
October to November	0.38	0.298	-0.13	0.311	0.141
November to December	0.75	0.139	-0.037	0.684	0.515
December to January	0.695	0.331	-0.104	0.656	0.456
January to February	0.294	0.329	-0.299	0.451	0.128
February to March	-0.406	.775*	0.107	-0.595	-0.205
March to April	-0.243	0.212	0.661	-0.527	0.225
April to may	0.012	0.083	.843*	-0.277	0.549
September to November	0.489	0.378	-0.236	0.44	0.166
October to December	0.408	0.433	0.107	0.062	0.213
November to January	.826*	0.15	-0.128	0.696	0.439
December to February	0.327	0.465	-0.135	0.293	0.193
January to March	0.082	.826*	-0.133	0.022	0.04
February to April	-0.338	0.455	0.601	-0.588	0.176
March to May	-0.192	0.361	0.731	-0.567	0.283
April to June	-0.21	0.438	0.717	-0.664	0.231
September to December	0.504	0.482	-0.096	0.3	0.216
October to January	0.657	0.372	-0.094	0.491	0.335
November to February	0.643	0.366	-0.201	0.574	0.328
December to March	0.115	.899**	0.059	-0.15	0.11
January to April	-0.006	0.621	0.541	-0.208	0.425
February to May	-0.28	0.605	0.641	-0.608	0.222
March to June	-0.255	0.454	0.512	-0.632	0.068
April to July	0.342	0.308	.827*	-0.133	0.693
October to December + February	0.308	.811*	-0.019	0.009	0.138
October to December + March	0.078	0.48	0.19	-0.258	0.056

Table 3. Contd.

October to December + April	0.316	0.326	.839*	-0.193	0.648
October to December + May	0.432	0.521	0.107	0.059	0.227
October to December + February to March	0.012	0.779*	0.139	-0.337	0.011
October to December + March to April	0.027	0.412	0.597	-0.394	0.301
October to December + April to May	0.397	0.482	.827*	-0.179	0.674
October to November + April	0.3	0.176	0.716	-0.013	0.628
October to November + February to March	-0.019	0.734	0.011	-0.237	-0.047
October to November + March to April	0.003	0.338	0.52	-0.311	0.272
October to November + April to May	0.415	0.376	0.751	-0.005	0.699
November to December + March to April	0.128	0.285	0.688	-0.332	0.42
November to December + April to May	0.624	0.218	0.927**	0.02	.892**
Annual (September to August)	0.469	0.717	0.231	0.183	0.475
Growing season	-0.323	0.476	0.438	-0.784*	-0.074
EPGS - growing season	0.049	.938**	0.299	-0.255	0.22

* and ** Correlation is significant at the 0.05 and 0.01 level respectively.

April to May, April to July, October to December plus April, October to December plus April to May and November to December plus April through May, but a better correlation (r = 0.89) was obtained with the November to December plus April and May precipitation (Table 3).The sample and stepwise regression equations for these precipitations and herbage yield of *S. arbosculoformis* are shown in Table 4. Stepwise multiple regressions with April to May and November to December plus Apr to May precipitation accounted for 94% of the variation in herbage yield of *S. arbosculoformis*.

Forage yield of *Artemisia seiberi* was mostly correlated with December to January precipitation (Table 3). The regression equation derived from the relationship of *Artemisia seiberi* forage production and November to December precipitation is: $Y = 0.046\ P_{Nov - Dec} + 0.2.55$ ($r^2 = 0.68$, $p = 0.022$). Where Y= estimated *Artemisia seiberi* forage production (kg ha^{-1}), P = precipitation (mm). Herbage yield of *Salsola tomentosa* was significantly correlated with precipitation of January and growing season, but a better correlation (0.847) was obtained with January precipitation (Table3). The regression models of *Salsola tomentosa* production are shown in the Table 5.

The stepwise multiple regression equation for these precipitations and Herbage yield of *S. tomentosa* are shown that the best relationship was with the January precipitation which accounted for 72% of the variation in yield of *S. tomentosa* (Table 5). Forage yield of *Astragalus podolobus* was significantly correlated with February to March, January to March, December to March, October to December plus February to March and the end of the growing season in previous year plus the new growing season precipitation, but a better correlation (r= 0.938) was obtained at the end of the growing season in previous year plus the new growing season (Table 3). The relationship between the yield of *Astragalus podolobus* and these precipitations are shown in Table 6.

Stepwise multiple regression analyses between yield of *Astragalus podolobus* and February to March, January to March, December March, October to December plus February to March and the end of the growing season in previous year plus the new growing season precipitation shows that the best relationship was with the growing season in previous year plus the new growing season precipitation which accounted 88% of the variation in yield of *Astragalus podolobus* (Table 6).

DISCUSSION

The influence of precipitation pattern on yield of four species (*Salsola arbosculoformis, Artemisia seiberi, Salsola tomentosa* and *Astragalus*

Table 4. Regression of *Salsola arbosculoformis* forage yield(Y, Kg ha^{-1}) on precipitation (P, mm) at Pashylogh site.

Regression equation	r^2	*P*
$Y = 0.131\ P_{Apr\text{-}may} + 10.07$	0.71	0.017
$Y = 0.095\ P_{Apr\text{ - }Jul} + 9.62$	0.68	0.022
$Y = .117\ P_{Oct\text{-}Dec\ +Apr} + 2.035$	0.70	0.018
$Y= 0.11\ P_{Nov – Dec + Apr\text{ -}may} + 0.33$	0.86	0.003
$Y = 0.09\ P_{Apr\text{-}may} + 0.073\ P_{Nov – Dec + Apr\text{ -}may} – 0.08$	0.94	0.04

Table 5. Regression of *Salsola tomentosa* forage yield(Y, Kg.ha^{-1}) on precipitation (P, mm) at Pashylogh site.

Regression equation	r^2	*P*
$Y = 0.093\ P_{Jan} + 0.997$	0.72	0.016
$Y = 10\ .88\ - 0.041\ P_{growing\ season}$	0.62	0.037

Table 6. Regression of *Astragalus podolobus* forage yield(Y, Kg ha^{-1}) on precipitation (P, mm) at Pashylogh site.

Regression equation	r^2	*P*
$Y = 0.016\ P_{Feb\text{-}mar} – 0.82$	0.60	0.041
$Y = 0.017\ P_{Jan\text{-}Mar} – 1.43$	0.68	0.022
$Y = 0.017\ P_{Dec\text{-}Mar} – 2$	0.81	0.006
$Y = 0.017\ P_{Oct\text{- }Dec + Feb} – 1.67$	0.66	0.027
$Y = 0.01\ P_{Oct\text{-}Dec + Feb\text{-}Mar} – 1.25$	0.61	0.039
$Y = 0.01\ P_{EPGS + Growing\ season} – 3.096$	0.88	0.002

podolobus) in the Pashylogh rangeland of Iran was studied for a period of 7 years (2003 to 2007 and 2009 to2010). The linear regression model was used to determine relations between precipitation and yield (Figure 1).

The result of the study revealed that increasing the length of the precipitation period improved the relationship between precipitation and yield. Precipitation pattern had more strong influence on the variations of annual forage production, and various period of precipitation had different effects on annual yield of species. The inclusion of various period of precipitation improved the relationship when correlated with forage production (Table 3).

This study showed that precipitation in previous fall and current spring had more effect on forage production. In the Pasylogh rangeland, total forage production can be estimated with the November to December plus April to May precipitation. Bagestani and Zare (2007) also found that the October, November and spring precipitation mostly influenced forage production in Yazd rangeland. Hanson et al. (1982) and Ehsani et al. (2007) reported that previous annual and seasonal precipitation has strongly influenced forage production in rangeland. Because, winter temperature is limited growth of species; therefore, species can not using winter precipitation. The various species differed greatly in their response to precipitation period. Yield of *Salsola arbosculoformis,* was strongly influenced by precipitation of November to December plus April to May (r^2 = 0.86), *Artemisia seiberi* by the December to January (r^2 = 0.68), *Salsola tomentosa* by January (r^2 = 0.72) and *Astragalus podolobus* by the growing season in previous year plus the new growing season (r^2 = 0.88). The different responses of the four species may be the result of differences in morphology and physiology.

This study showed that precipitation in previous fall and current spring had more effect on forage production. Bagestani and Zare (2007) found that the October, November and spring precipitation mostly influenced forage production in Yazd rangeland. Hanson et al. (1982) and Ehsani et al. (2007) reported that previous annual and seasonal precipitation has strongly influenced forage production in rangeland. Winter temperature is limited growth of species; therefore, species can not using winter precipitation.

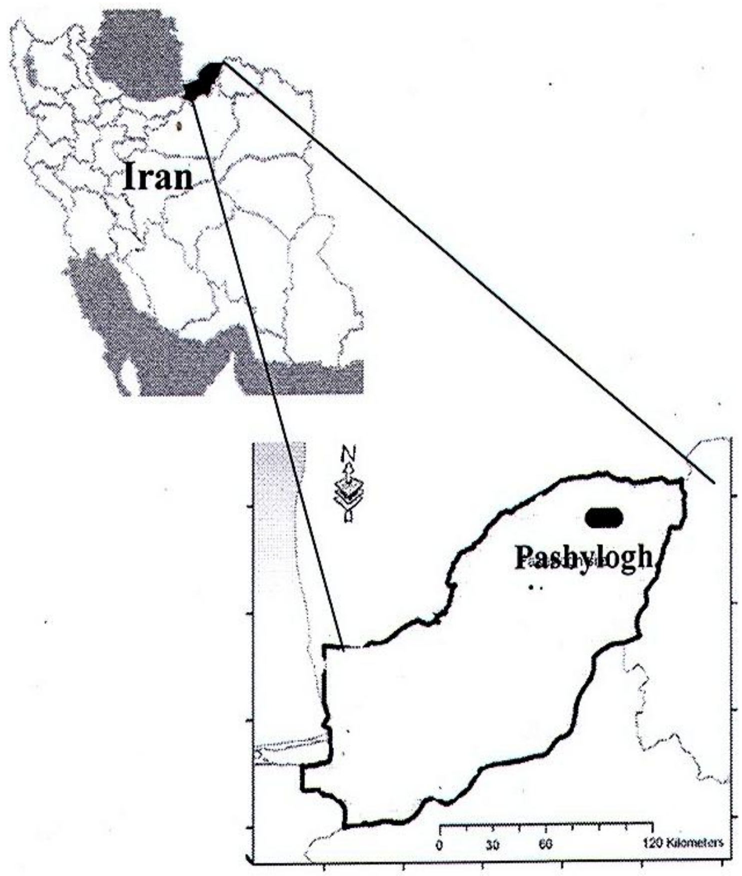

Figure 1. Location of Pashylogh study site, Iran.

REFERENCES

Andales AA, Derner JD, Ahuja LR, Hart RH (2006). Strategic and tactical prediction of forage production in northen mixed – grass prairire. Rangeland Ecol. Manage., 59: 576-584.

Arzani H, Kingh GW (1994). A double sampling method for estimating forage from cover measurement, 8 th biennial rangeland conference. Australia Rangeland Soc., pp. 201-202.

Baghestani MN, Zare MT (2007). Investigation of relationship between annual precipitation and yield in Steppe range of Poosht- Kooh region of Yazed provience. J. Pajouhesh and Sazandegi, 75: 103-107.

Bets JD, Svejcar T, Miller RF, Angell RA (2006). The effects of precipitation timing on sagebrush steppe vegetation. J. Arid Environ., 64: 670-697.

Duncan DA, Woodmansee RG (1975). Forecasting forage yield from precipitation in California's annual rangeland. J. Range Manage., 28: 327-329.

Ehsani A, Arzani H, Farahpor M, Ahmadi H, Jafari M, Jalili A, Mirdavodi HR, Abasi H R, Azimi MS (2007). The effect of climatic condition on range forage production in steppe rangelands, AKhtarabad of Saveh. Iranian J. Range Desert Res., 14: 260-269.

Fetcher N, Trlica MJ (1980) . Influence of climate on annual production of seven clod desert forage species. J. Range Manage., 33: 35-37.

Fynn RWS, O'Connor TG (2002). Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in semi-arid savanna, South Africa. J. Appl. Ecol., 37: 491-507.

George MR, Willliams WA, Macdouglad NK, Clawson WJ, Murphy AH (1989). Prediciing peak standing crop on annual range using weather variable. J. Range Manage., 42: 506-513.

Hanson CL, Wight JR, Smith JP, Smoliak S (1982). Use of historical yield datd to forecasting range herbage production. J. Range Manage., 35: 614-616.

Hien L (2006). The impacts of grazing and rainfall variability on the dynamics of Sahelian rangeland. J. Arid Environ., 64: 488-504.

Khumalo G, Holechek J (2005). Relationships between Chihuahuan desert perennial grass production and precipitation. Rangeland Ecol. Manage., 58: 239-246.

Mclean A, Smith JHG (1973). Effects of climate on forage yield and tree-ring widths in British Columbia. J. Range Manage., 26: 416-419.

Murphy AH (1970) . Predicted forage yield based on fall precipitation in California annual grasslands. J. Range Manage., 23: 363-365.

Pumphery FV (1980). Precipitation, temperature and herbage relationships for a pine woodland site in northeastern Oregon. J. Range Manage., 33: 307-310.

Shiflet TN, Dietz HE (1974). Relationship between precipitation and Annual rangeland herbage production in southeastern Kansas. J. Range Manage., 27: 272- 276.

Smoliak S (1986) . Influence of climatic on conditions on production of Stipa bouteloua prairie over a 50 – year period. J. Range Manage., 39: 100-103.

Sullivan S, Rohed R (2002). On non- equilibrium in arid and semi- arid grazing system. J. Biogeogr., 29: 1595-1618.

Wight RJ, Hanson CL, Whitmer D (1984). Using weather records with a forage production model to forecast range forage production. J. Range Manage., 37: 3-6.

Willey BK, Pieper RD, Southward GM (1992). Estimating herbage standing crop from rainfall data in Niger. J. Range Manage., 45: 277-284.