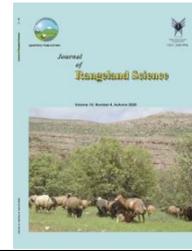


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**Research and Full Length Article:**

## The Effect of Soil Moisture and Climatic Index of Evapotranspiration on Forage Production in Rangelands of Dehsir, Yazd province, Iran

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**Abstract.** Estimation of long-term pasture production using important factors of climate and soil characteristics on forage production is inevitable. Reduced water and precipitation are important factor limiting production of fodder, especially in arid and semi-arid areas. Water use efficiency in these areas is the amount of water stored in the root orientation early in the growing season and water spread area of effective rainfall in the growing season that is used for evaporation and transpiration in plants. One of the important sections of the hydrological cycle is evapotranspiration. The transpiration directly affects forage production. The basis of estimating the water requirement of plants is the potential evapotranspiration which can be calculated by different methods. In this study, forage production in steppe rangelands of Dehsir, Yazd province, Iran were estimated using climatic index of potential and actual evapotranspiration and soil characteristics using Penman-Montith (Cropwat 8.0 software). The climatic data were provided from Dehsir Rainfall and Abarkooh Synoptic Station. Soil samples were taken by Auger at the beginning period of the growing season and soil moisture content was obtained weighing the soil before and after drying to constant weight in oven (100°C) in 2013. Then the regression model for estimation of forage production using soil moisture and evapotranspiration as independent variables was developed. The results showed that forage production had a strong correlation with the climatic index of actual evapotranspiration according to the estimation of actual evapotranspiration in a ten-year period, a model was provided for forage production as  $Y_a=194.85+1.132(ET_{act})$ . It could be said that actual evapotranspiration as an index for climate yield is one of the fundamental factors in estimating forage production.

**Key words:** Forage production, Water requirement of plants, Effective rainfall, Dry and semi-dry rangelands

## Introduction

Rangeland forage production measurement has always been a key issue due to its importance in rangeland management and annual grazing regulation (Smart *et al.*, 2005). Most of rangelands are located in arid and semi-arid regions in the world (Benie *et al.*, 2005) and there is much variation in their climate in different years. In such areas estimation of forage production are difficult and uncertainty (Forrest and Hyder, 1985). So, knowing that the climate factors that have a great impact on plants growth, helps to have a more accurate prediction for feed. Also, soil characteristics have major effect on plant production. Therefore, in addition to the effect of climatic parameters, there are differences in forage production due to soil factors. In fact, the performance of plants is affected by climatic, soil and plant factors and estimation of long-term pasture production, therefore, knowledge of climate and soil properties on forage production is inevitable. Many studies have investigated the relationship between plant production and precipitation (as the most influential climatic index) and proposed a model (Akbarzadeh *et al.*, 2006; Bates *et al.*, 2006; Mansouri *et al.*, 2013; Noori *et al.*, 2014; Fakhimi *et al.*, 2015; Jaberlansar *et al.*, 2017; Fakhar Izadi *et al.*, 2019, Dastorani *et al.*, 2019 Mohammadi *et al.*, 2020). However, rainfall alone cannot be a suitable factor for determining plant production. Since all of rainfall is not available for the plants. Some of it may be runoff or decreased via evapotranspiration. So, the effective precipitation that obtained from the fraction of runoff and evapotranspiration from the amount of rainfall and is highly correlated with the rainfall use efficiency by the plant (Hein, 2006). In general, plants consume water in the transpiration process during growth period stages. Evaporation from the soil surface may also occur. The sum of these processes is called evapotranspiration. Evapotranspiration is an important part of the hydrology cycle

that affects the contribution of transpiration to the rate of direct evapotranspiration (Ehsani *et al.*, 2012). Nowadays, estimation of water requirement of plants for planning and implementation of range management and improvement as well as to estimate long-term historical rangeland production and livestock grazing capacity by FAO researchers have been suggested. Mohammadi Moghadam *et al.*, (2013) modeled forage production using temperature parameters and evapotranspiration in the Polouer experimental station in Mazandaran province, Iran. Bases on their results, the model derived from evapotranspiration could provide a better estimation of forage production in that area. Also, one of the most important factors limiting rangeland production in arid and semi-arid regions is the lack of rainfall. In these areas, water use efficiency includes water stored in the root development zone in the early growing season plus rain water in the growing season that is used for evapotranspiration. The term of water productivity is expressed as the ratio of crop production to evapotranspiration that are calculated by Blani-Kridel and Hargreaves-Samani models (Ehsani *et al.*, 2012). Many researchers have attempted to estimate forage production through evapotranspiration and soil moisture during the early growing season. The water balance model was used to estimate forage production in the grassland ecosystem (Wight and Hanks, 1981). There are models predicted the forage production using climatic indices (precipitation, evapotranspiration and actual potential transpiration) and the soil moisture the early growing season. Climatic data (soil moisture in early growing season, daily rainfall, mean temperature and sunlight) were investigated using water balance equilibrium model to estimate pasture forage production (Wight *et al.*, 1984; Ehsani *et al.*, 2012; Fakhimi *et al.*, 2019). Their results showed that there was a close relationship between these factors and

forage production that it can be estimated using long-term water balance model. The use of long-term climatic information has been investigated in rangelands of the semi-arid region of Africa (Hahen *et al.*, 2005). Their results indicated that plant production had a direct relationship with soil moisture storage. The study of forecasting and estimation of forage production through climatic data showed that one can estimate rangeland production using Rangetek model with considerable confidence (Kruse and Heitschmidt, 2007). Also, application of soil and water balance model in the dry and semi-arid region in Senegal showed that the plants had optimum utilization through soil depth moisture due to the development of bivalve root and that it was related to soil moisture regime (Kizitoel *et al.*, 2007). Estimates of long-term rangeland production with different rainfall patterns in the steppe rangelands of Dehshir, Yazd, Iran were also investigated (Fakhimi *et al.*, 2015). Their results indicated that the rainfall of the previous year and the rainfall of the growing season were the most important factors in estimating long-term production in rangelands.

In this study, its objective was to estimate relationship between climatic index as evapotranspiration on forage yield in arid rangelands of Yazd province, Iran. Then, to develop a regression model between soil moisture content and climatic index of evapotranspiration with long-term rangeland production.

## Materials and Methods

### The study area

The study area covers an area of 8200 ha with a geographical range between 53°31' to 53°34' eastern longitude and 31°18' to 31°28' northern latitude, with an altitude of 1700-2700 m above sea level and an average slope of 2 to 5% under the Dehshir Basin in the Southwest of Yazd province, Iran (Fig. 1).

The climate of the region is cold and dry (dry climate) according to the Amberg

method. The average rainfall is 100 to 120 mm and the average annual temperature is between 13.7 and 15.3°C. The topsoil contains silty loamy texture and *Artemisia sieberi-Hertia angustifolia* forms the dominant cover of the region. The most important plants in the area are: *Artemisia sieberi*, *Hertia angustifolia*, *Astragalus schystocalyx*, *Acanthophyllum spinosum*, *Dendrostellera Lessertii*. The pasture status in this unit is weak and its tendency is constant. The existence of several sheep herds and the location of Dehshir village and other villages within this area have eliminated and weakened some vegetation and greatly destroyed the rangeland type. The dominant type of livestock is the sheep and goat.

### Research Method:

To develop a model of forage estimation using climatic index of evapotranspiration, actual pasture forage production and meteorological data (nearest synoptic station) were collected for ten years in Dehshir basin. Then the climatic indices (reference evapotranspiration, potential and actual evapotranspiration) and effective rainfall were determined based on Penman-Montith equation using Cropwat8.0 software. Runoff was estimated using SCS method. Previous soil moisture and soil moisture content of the growing season was measured. The soil and vegetation characteristics were determined by field, laboratory, and library finally analyzed. The steps of the calculation were as follows:

#### a) Climatic Data:

Long-term climatic data were provided over ten years (2003-2013) including rainfall (daily, monthly, annual) temperature (minimum and maximum daily and monthly mean) of sunlight, mean daily wind speed and percentage of relative humidity from Abarkuh Synoptic meteorological Station with latitude 31°02' and longitude 53°35' and altitude of 1481 m above sea level and Dehshir Rainfall Station with longitude 31°27' and

longitude  $53^{\circ}45'$  and altitude of 1833 m above sea level.

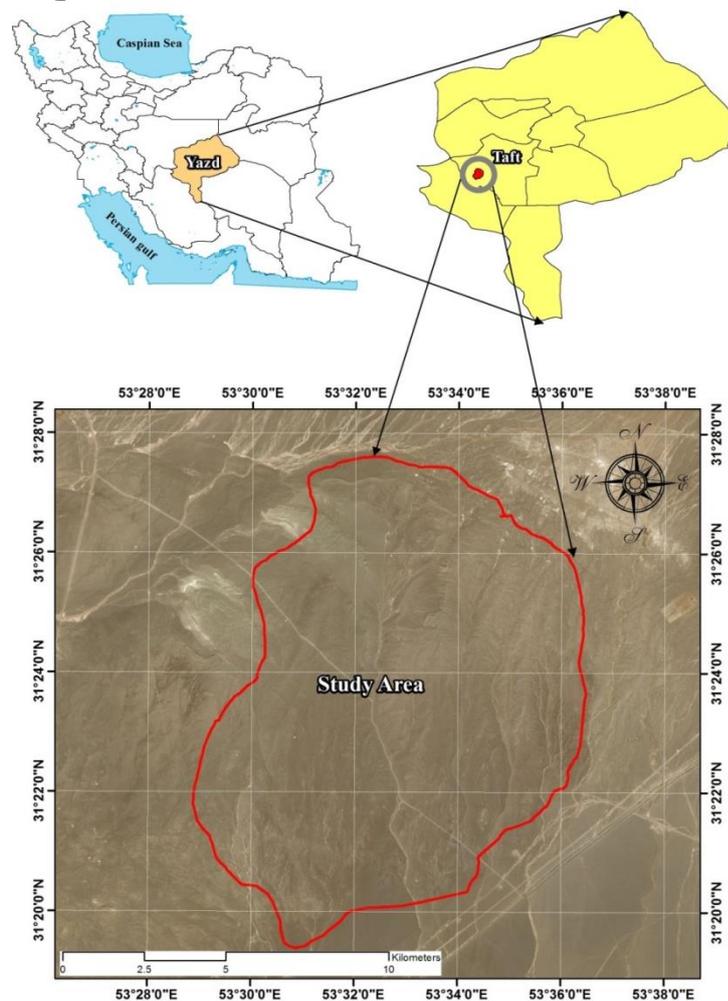


Fig. 1. The map of site location in rangelands of Dehshir, Yazd province, Iran

### b) Forage Production:

For measuring production and canopy cover (10-year period), sixty  $2\text{m}^2$  plots were laid parallel along four 400 m transects with 100 m intervals. So that in each strip 15 plots of  $2\text{m}^2$  were laid with distance of first plot to strip 10 m and other plots 28 m (Fakhimi *et al.*, 2019). Transects have been flagged for estimating pasture production and assessment were made over 10 years by financial support of the Agricultural Insurance Fund. The data were recorded in the sampling form including samples location; transect number, plot number, harvest date, species name, species vitality, vegetation percentage, litter percentage, rock and gravel and bare soil percentage. In order to measurement of the forage production, the above ground for each species were

separately cut and weighted in twenty percent of the plots (15 plots) and their canopy cover was measured in all plots. Then, the harvested fresh forage place in open environment for two weeks, dry forage weight and recorded for each species. Estimation of other plots was made using a double sampling procedure suggested by (Arzani and King, 1994). The collected data of canopy cover and forage production were entered into Excel software and SPSS 19 software was used for statistical analysis.

### c) Soil Properties:

In each transect a soil profile was drilled to the maximum root penetration depth and samples were performed on profiling and moisture measurement on the layers. Soil Samples were taken in three depths of 0-

30, 30-60 and 60-80 cm depths according to the plant root system. Soil texture was determined by hydrometric method using tissue triangle to determine the soil bulk density at the site. The intact specimens were taken from specific depths of the study area and transferred to the laboratory. In this study, soil samples in root extension area was taken directly by Auger at the beginning and during of growing season (March to June). The soil moisture content was obtained by weighing the soil before and after drying to constant weight in oven (100°C). It should be noted that the average moisture content during March to June was considered as the growing season moisture.

Field capacity and wilting point at the study site were determined using pressure plate machines in the laboratory. For this purpose, soil moisture was measured at 0.1 atmospheric pressure. Total Available Water (TAW) within the root zone of the plant is equal to the difference in soil water content at two levels of field capacity and at permanent wilting point, calculated as follows:

$$TAW=1000(\theta_{FC}-\theta_{WP})Z_r \quad (1)$$

Where:

TAW= Total available soil water at plant root development depth (mm)

$\theta_{FC}$ =Amount of soil water at field capacity ( $m^3/m^3$ ),

$\theta_{WP}$ =Soil water content at permanent wilting point ( $m^3/m^3$ ),

$Z_r$ =The depth (range) of plant root development (m),

A fraction of usable soil water that can be absorbed without causing water stress is called readily available water (RAW) (Darbandi *et al.* 2008).

The readily available water is calculated as follows:

$$RAW=P.TAW \quad (2)$$

Where:

RAW= readily available water at the root of the plant (mm)

TAW= Total available soil water at plant root development depth (mm)

P = Discharge coefficient (varies for different types of plants).

The average fraction of total water that can be drained from the depth of root development before water stress (evapotranspiration reduction) and its P is between zero and one variable.

This coefficient usually ranges from 0.3 for plants with shallow roots and high evapotranspiration (more than 8mm/day) to 0.7 for plants with deep roots and low evapotranspiration (less than 3mm/day) (Darbandi *et al.* 2008).

#### d) Evapotranspiration Estimation

In most parts of the world, including Iran, climate-based methods are used to estimate reference evapotranspiration and the Penman-Montith FAO method. The climatic indices were calculated from the Penman-Montith FAO equation as follows on a daily time scale during the growing season from climate data and soil physical characteristics for ten years using the new FAO software (CROPWAT8).

Penman-Montith Equation is calculated hybrid equation as follows

$$ET_0 = \frac{0.48\Delta(Rn-G) + \gamma \left( \frac{900}{T+273} \right) U_2 (e_s - e_a)}{\Delta + \gamma(1+34U_2)}$$

(3)

Where:

$T_0$  = Reference plant evapotranspiration (mm/day)

Rn = Net inlet radiation to the plant surface ( $MJ/m^2/day$ )

G=soil heat flux

In the Penman-Montith FAO equation for calculating daily, weekly, ten-day, or monthly evapotranspiration, in addition to data such as solar radiation (sunshine), minimum and maximum air temperatures, air humidity, wind speeds, local meteorological coordinates (elevation of Sea level and latitude are also required (Darbandi *et al.* 2008).

The Penman-Montith FAO equation is a simple and accurate representation of the physical and physiological factors affecting the evapotranspiration process.

Using Penman-Montith's definition of reference plant evapotranspiration, we can calculate the plant coefficients by linking the measured plant evapotranspiration (ETC) to the calculated reference evapotranspiration. The factor of the plant coefficient is as a set of physical and physiological differences between the plants and the reference surface. In this study, according to the calculation of reference evapotranspiration and actual evapotranspiration, plant coefficients were calculated from the following relationship (Darbandi *et al.* 2008).

$$KC = \frac{ETc}{ETo} \quad (4)$$

Where:

KC: Vegetation coefficients,

ET0: Reference evapotranspiration

ETc: Measured evapotranspiration of the plant

#### e) Plant Growth Traits (Rangeland):

Start date of growth, vegetation coefficients at growth stage, growth period, root depth (primary, intermediate, final), discharge coefficients and plant height were calculated and determined according to FAO 56 report (Allen *et al.*, 1998).

The period of plant growth for four distinct stages including early stage, development stage, mid-season stage and end-season stage were determined as 15, 20, 22 and 65 days, respectively, this data were based on the average phenological period of dominant plants and duration of growing season.

#### f) Maximum rooting depth:

After digging the soil profile, the maximum rooting depth was measured according to the rooting depth.

#### g) Effective Rainfall:

The effective rainfall is the part of the rainfall that penetrates into the soil (depth of 10-12cm). The effective rainfall in the growing season was calculated by Soil

Conservation Service (SCS) method using CROPWAT 8 software.

#### h) Surface runoff:

In this study, the runoff was estimated from the proposed method of the Soil Conservation Service (SCS). In this method, the height of the runoff is calculated as follows:

$$R = \frac{(P-0.2S)^2}{(P+0.8S)} \quad (5)$$

if  $P < 0.25 \rightarrow R = 0$

Where:

R: Runoff height

P: Rainfall height

$$CN = \frac{1000}{CN} - 10 \quad (6)$$

$$S = \frac{S_{max} \cdot (UL - S_m)}{UL} \quad (7)$$

$$S_{max} = 25400 / (254 + CN) \quad (8)$$

Where:

CN= the curve number that related to the amount of water infiltration in the basin.

S: the factor of water retention at ground level

In the modified method, Parameter of soil moisture holding capacity (S) related to soil water capacity is first calculated using the following formula:

$S_m$ =amount of water in the soil of the root zone before rainfall

UL=the upper limit of soil storage capacity in the root zone, which is usually equal to the amount of moisture in the field capacity.

$S_{max}$  =the maximum size of S is calculated by the N and I moisture conditions using the SCS

## Results

#### a) Vegetation cover:

The dominant vegetation type of Dehshir rangelands is *Artemisia sieberi-Hertia angutifolia* with an area of 2850 ha. The list of plant species identified in the area during the years 2003-2013 is given in Table (1).

**Table 1.** List of plants available at Dehshir site during 2003-2013

Spices name	Family	Class of palatability for sheep	Life from
<i>Alhagi persarum</i>	Asteraceae	III	Perennial Forb
<i>Acanthophyllum spinosum</i>	Caryophyllaceae	III	Perennial Shrub
<i>Artemisia sieberi</i>	Asteraceae	I	Perennial Shrub
<i>Astragalus schystocalyx</i>	Fabaceae	III	Perennial Shrub
<i>Boissiera squarrosa</i>	Poaceae	III	Annual Grass
<i>Bromus tectorum</i>	Poaceae	II	Annual Grass
<i>Dendrostellera. lessertii</i>	Thymelaceae	III	Perennial Shrub
<i>Lactuca serriola</i>	Asteraceae	III	Perennial Forb
<i>Noaea macronata</i>	Chenopodiaceae	III	Perennial Shrub
<i>Pteropyrum aucheri</i>	Polygonoideae	III	Perennial Shrub
<i>Salsola sp.</i>	Chenopodiaceae	II	Perennial Forb
<i>Scorzonera mucida</i>	Asteraceae	II	Perennial Forb
<i>Stipa barbata</i>	Poaceae	II	Annual Grass
<i>Stipagrostis plumosa</i>	Poaceae	III	Perennial Grass

before and 24 hours after rainfall. Their mean results are presented in Table 2.

Physical characteristics and soil moisture storage, especially stored moisture due to earlier rainfall, is one of the main factors of plant growth especially forage production. Because the actual evapotranspiration during the growing season was influenced by the rainfall of the growing season and the moisture stored in the preceding months. The soil moisture properties are shown in Table 3.

**Table 2.** Average moisture content of soil profile layers and root extension depth at different times

Measurement time	Soil moisture content (%)
The first of March (Beginning of growing season)	5.1
Mid-April	4.8
Mid-May	4.2
The second half of June(growing End of season)	3.9

**Table 3.** Soil properties in Dehshir area

Soil profile (cm)	Density (g/cm <sup>3</sup> )	Field Capacity (%)	Wilting Capacity (%)	Total available Water (mm/m)
0-30	1.52	14.28	12.30	9.05
30-60	1.59	16.30	12.96	15.93
60-80	1.68	24.70	10.65	10.65
Total				35.6

### C. Surface runoff:

To determine the maximum moisture content in the root zone, the amount of field capacity determined in the laboratory was used. The results of the studies in Dehshir area showed that, the CNi number for the normal case is 86 and the runoff starts at 14 mm, that this amount of runoff during the growing season was negligible during the statistical period.

### B. Soil Properties:

The soil was shallow to semi deep with gravel and contains large amounts of lime (47%). The soil texture is light (sandy to sandy loam) and contains relatively large pores. Soil EC varied from 4 to 19 mmohs/cm and soil pH varies from 7.6 to 7.8.

Soil moisture content was measured at the beginning, middle and end of the growing season in different soil layers and at the depth of root propagation in the soil

### D. Results of Cropwat 8.0

Input factor for production estimation Plant data in the Dehshir area were:

Starting date: late February

Maximum rooting depth: 80 cm

Vegetation coefficients:

$K_{Cini}=0.35$   $k_{Cmind}=0.85$   $k_{Cend}=0.8$

### Stages of plant growth:

First step = 15 days

Development step=22 days

Mid-step = 60 days  
 Finishing step = 20 days  
 Beginning of growth= 0.1 - 0.3  
 Rooting depth= 0.25 - 0.85(m)  
 Critical depletion (fraction) =0.5-0.7  
 Yield response=0.2 - 0.6 - 0.6-0.9  
 Crop height= 0.50 (m)

**Data of soil:**

According to the calculation of Table 2, TAW is 35.6, after calculating in millimeters per meter it was 44.5.  
 $TAW=35.6 \times 100/80=44.5$   
 Total available soil moisture (FC-WP) =44.5 mm/m  
 Maximum infiltration rate=204.2(mm/day)  
 Maximum rooting depth=80 (centimeters)  
 $TAM=(1-F.M/FC-PWP) \times 100$   
 Initial soil moisture depletion (TAM %) =64%

Initial available soil moisture =13.8

**Estimation model of forage production**

The results of correlation between annual forage production with soil moisture and climatic indices of evapotranspiration are shown in Table 4. Correlation between forage production as a dependent variable with soil moisture and climatic indices of evapotranspiration as an independent variable showed that there is the highest correlation between production and actual evapotranspiration so that actual evapotranspiration and previous soil moisture Justifies for 78% & 61% of annual forage production changes respectively (Table 4).

**Table 4.** Correlation between annual forage production as dependent variable with Soil moisture and climatic indices of evapotranspiration in Dehshir region, Yazd Province

Independent variable	R (correlation)	P value
Previous soil moisture	0.61**	0.019
Soil moisture of the growing season	0.35	0.260
Potential evapotranspiration ( $ET_{pot}$ )	0.52*	0.049
Actual evapotranspiration ( $ET_{act}$ )	0.78**	0.006

The value of reference evapotranspiration ( $ET_r$ ), potential evapotranspiration ( $ET_{pot}$ ), actual evapotranspiration ( $ET_{act}$ ) and effective rainfall are listed (Table 5). Based on the climate index (actual evapotranspiration)

and forage production, the estimation model of production was calculated. a and b are calculated from a linear regression using the actual production and the actual evapotranspiration of model.

$$Y=1.132ET_{act}+194.85(10)$$

**Table 5.** Reference, potential and actual evapotranspiration, coefficient of vegetation (habitat) and estimation of production in Dehshir region

Year	Actual Production (kg/h)	Effective rainfall	Habitat coefficient	Kc	$ET_r$	$ET_p$	$ET_a$	Estimated production (kg/h)
2003-2004	286	93.4	0.18	0.28	1652.6	475.5	85.3	291.70
2004-2005	273	62.5	0.15	0.29	1981.4	489.2	72.4	276.68
2005-2006	230	87.3	0.10	0.10	1652.2	508.4	50.1	251.46
2006-2007	320	50.3	0.14	0.32	1685.4	547.2	75.2	279.85
2007-2008	250	17.4	0.96	0.33	1703.2	561.4	54.1	256.99
2008-2009	220	12.8	0.37	0.34	1754.2	601.8	22.3	220.02
2009-2010	235	35.8	0.09	0.34	1682.4	567.4	52.1	253.72
2010-2011	245	92.5	0.04	0.34	1743.1	594.2	24.2	222.17
2011-2012	260	91.4	0.12	0.29	1693.5	503.1	60.4	263.11
2012-2013	260	63.3	0.13	0.29	1542.3	488.1	62.0	264.92
Mean	257.9	63.9	0.14	0.29	1706.2	533.6	55.8	256.06

Reference evapotranspiration ( $ET_r$ )

Potential evapotranspiration ( $ET_{pot}$ )

Actual evapotranspiration ( $ET_{act}$ )

Vegetation coefficients (KC)

## Discussion and Conclusion

Soil moisture, especially stored moisture due to previous precipitation, is one of the factors for growth and production of forage plants in arid and semiarid regions. In these areas, the lack of rainfall is considered as a limiting factor of forage production growth and the actual evapotranspiration of the plant in the growing season is not proportional to the rainfall of the growing season in these areas (Ehsani *et al.*, 2009). The results showed that among climatic indicators of evapotranspiration, actual evapotranspiration is more correlated with forage production. The result of this study was consistent with the findings by other researchers (Doorenbos and Kassem 1979; Hanks and Ramussen, 1982; Taylor *et al.*, 1983; Gommès, 2006; Kizitoo *et al.*, 2007; Ehsani *et al.*, 2012 and Fakhimi *et al.*, 2019), that they have emphasized that actual evapotranspiration was effective on forage growth and production. Accordingly, there was a strong correlation between the total amount of forage produced and the total amount of actual evapotranspiration and the correlation between actual evapotranspiration and production was high and the relationship between the amount of dry matter produced and evapotranspiration was linear. Often estimates of forage production in arid regions are calculated based on actual evapotranspiration rates which form the basis of the equations of growth and production. However, most rangelands are in climatic zones with potential evapotranspiration greater than annual rainfall and actual evapotranspiration greater than the rainfall growing season. This value has even been calculated twice or more (Ehsani *et al.*, 2009). Estimates of potential evapotranspiration during the eruption period the study area indicate, the potential evapotranspiration is about 9 times higher than the average of the actual evapotranspiration. On the other hand, the actual evapotranspiration rate is about 1.2

times higher than the average rainfall of growing season in Dehshir region. In other words, the actual evapotranspiration exceeds the amount of rainfall of growing season. This indicates that the plant used the stored moisture for actual evapotranspiration. This result indicates that the rainfall of growing season does not provide the water requirement of the plants. Therefore, plants use the stored soil moisture from previous rainfall. These results were consistent with the findings of Karabulut, 2002; Laidlaw, 2005; Ehsani *et al.*, 2009 and Fakhimi *et al.*, 2019. They have emphasized that the moisture stored during the rainfall of growing season and previous rainfall was very important for the growth and expansion of vegetation and forage production. On the other hand, evapotranspiration was introduced and used as an index of product performance by (Doorenbos and Kassem, 1979; Hanks and Rasmussen, 1982), that consistent with the Water and Climate Balance Model (Rojas *et al.*, 2003) and the water balance model of FAO (Rijks *et al.*, 2003; Gommès, 2006).

Consequently, rainfall in the steppe regions alone is not a determinant of forage production, rather, precipitation in addition to stored moisture from previous rainfall, according to the results of the study; affect the process of evapotranspiration and production. In addition to climatic factors, evapotranspiration rates depend on soil and plant characteristics, phenological stages of plant species, and other environmental and management factors. The amount of infiltration into the soil depends on the type of soil and vegetation. Of course, the most important factor in soil permeability is the percentage of clay, loam and sand or soil texture. Heavier soil texture, the less intensity of water infiltration in soil. Important soil morphology factors such as texture, structure and bulk density are very effective in water infiltration, moisture retention and consequently in establishment and growth of plant species. Also factors such as rooting depth, soil

water potential, nutrient absorb and nutrient production are also affected by the amount of moisture in the soil (Ehsani *et al.*, 2012).

In general, it can be concluded that using this model to relate soil and water regimes and plant and climate characteristics to plant growth and production is a bonus for rangeland managers. This model and equation can be applied in regions with similar vegetation and climatic conditions. Also, this model can be used to determine forage production under drought conditions in rangelands.

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## تأثیر رطوبت خاک و شاخص اقلیمی تبخیر و تعرق بر تولید مراتع خشک و نیمه خشک (مطالعه موردی: مراتع حوزه دهشیر یزد)

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**چکیده.** برآورد تولید بلند مدت مرتع با آگاهی از عوامل مهم تأثیرگذار (اقلیم و خاک) بر میزان تولید علوفه امری اجتناب ناپذیر هست. کمبود آب و بارش یکی از مهم ترین فاکتورهای محدود کننده تولید علوفه مراتع در مناطق خشک و نیمه خشک است. در این مناطق بازدهی مصرف آب عبارتند از آب ذخیره شده در ناحیه توسعه ریشه در اول فصل رویش به علاوه آب ناشی از بارندگی در فصل رویش که به صورت تبخیر و تعرق مورد استفاده قرار می گیرد. یکی از بخش های مهم چرخه هیدرولوژی تبخیر و تعرق می باشد. میزان تعرق از سطح گیاه به طور مستقیم بر تولید اثرگذار است. مبنای برآورد نیاز آبی گیاهان، تبخیر و تعرق پتانسیل است که به روش های مختلف محاسبه می شود. در این مطالعه مقادیر تبخیر و تعرق واقعی و پتانسیل با استفاده از داده های آب و هوایی ایستگاه کلیما تولوژی دهشیر و ایستگاه سینوپتیک ابرکوه استفاده شد و نمونه خاک در اول فصل رشد و دوره رویش گیاهان به وسیله آگر در سال ۱۳۹۲ برداشت شد و رطوبت خاک به روش وزنی اندازه گیری شد با استفاده از روش Penman-Montith به کمک نرم افزار cropwat8.0 تولید علوفه در مرتع دهشیر یزد برآورد شد. با استفاده از معادله رگرسیون برآورد تولید علوفه از طریق رطوبت خاک و شاخص اقلیمی تبخیر و تعرق برازش داده شد. نتایج نشان داد میزان تولید علوفه همبستگی مثبت و معنی داری با شاخص اقلیمی تبخیر و تعرق واقعی دارد و در نتیجه معادله برآورد تولید علوفه با استفاده از تبخیر و تعرق واقعی (ET) در دوره ده ساله (ترسالی و خشک سالی) تعیین شد  $(Y_a = 194.85 + 1.132ET_{act})$ . بنابراین می توان بیان داشت که تبخیر و تعرق واقعی به عنوان عملکرد اقلیمی یکی از فاکتورهای اساسی در برآورد تولید علوفه است.

**کلمات کلیدی:** تولید علوفه، نیاز آبی گیاهان، بارندگی موثر، مراتع خشک و نیمه خشک