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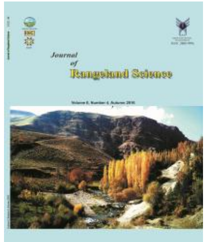

Research and Full Length Article:

The Effects of Climatic Parameters on Vegetation Cover and Forage Production of Four Grass Species in Semi-steppe Rangelands in Mazandaran Province, Iran

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Abstract. The vegetation cover and rangeland production are the most important factors to determine the proper planning system for effective utilization and management of rangelands. In this research, the effect of climatic factors (temperature and rainfall) were studied on vegetation cover and forage production of four species (*Festuca ovina, Bromus tomentellus, Dactylis glomerata and Agropyron trichophorum*) during 2002-2006 and in 2013 in a semi-steppe area in Polur rangeland, Mazandaran Province, Iran. The climatic factors were annual rainfall, growing season rainfall, growing season plus previous year rainfall, growing season rainfall of March, annual mean temperature and growing season temperature. For this purpose, some plots with a systematic distribution were selected. The vegetation cover and forage production were measured. The relationships between vegetation indices and climatic factors were assessed for each species using stepwise regression. The results demonstrated that the plant species had responded to rainfall and temperature fluctuations. However, the responses were different in various species. Among the important climatic factors, the growing season rainfall of March was the most effective index for *B. tomentellus* and *A. trichophorum* vegetation cover and forage production as well as on *D. glomerata* vegetation cover. The forage production of *F ovina* was influenced by the growing season plus the previous year rainfall. According to the results, the forage production and vegetation cover of these grass species could be estimated based on rainfall data. Therefore, with the knowledge of the effects of rainfall year fluctuations on vegetation indices over a long period, it is possible to make the necessary predictions for optimizing the management of rangelands.

Key words: Polur rangeland, Forage Production, Vegetation Cover, Rainfall, Temperature

Introduction

The effects of rainfall and temperature on vegetation cover and forage production are often studied with the purpose of analyzing and evaluating the vegetation response to rainfall and temperature regimes. In this field, many researchers have attempted to investigate the relationship between vegetation indices, the amount of rainfall and temperatures throughout the year, and different seasons and periods, and had introduced the most effective rainfall variables for vegetation cover, yield, and finally grazing capacity for long-term use in different regions (Smart *et al*., 2007). Different plants respond differently to climatic factors; therefore, the estimation of forage production based on drought for different plant communities is variable (Smart *et al*., 2007). The reaction of plants to rainfall varies according to the vegetative form and root system as well as the time and distribution of rainfall. Grass with a shallow root system, which had the maximum of 30 cm depth, can only absorb the saturated water in this depth; therefore, a higher amount of rainfall out of the growing season does not have any effect on its growth. However, woody plants with deep roots can absorb their required water from the moisture that is stored in deeper depths of the soil (Walter, 1979) Therefore, grass mostly dominates the regions with spring and summer rainfall patterns in which the rain seasons begin with the increased temperature. Khumalo and Holechek (2005) stated that the growing season rainfall has a high impact on forage production. They found a significant correlation between the total rainfall (December to September) and the yield of perennial grasses in Chihuahuan desert rangeland in southern-central New Mexico in a 34-year period. Laidiaw (2005) has also predicted the long-term rangeland production by rainfall, and the results indicated a direct relationship between forage production and rainfall. Hahn *et al*. (2005) reported that the rainfall was the most effective indicator to determine the rangeland production. Similarly, Munkhtsetseg *et al*. (2007) stated that the period of high temperatures could limit plant growth without a significant reduction in the amount of rainfall. Hadian *et al*. (2013) had studied the effect of rainfall on vegetation changes in Semirom and Lordegon regions of Iran. Their results showed that the effect of rainfall differs in various regions depending on plant growth form and ecological conditions. Therefore, the rangeland vegetation had the highest correlation with the spring rainfall and was related to the annual rainfall in the forest area; furthermore, in rangelands, the impact of rainfall was different according to the dominant plant species. Jagerbrand *et al*. (2009) investigated the plant communities in Sudan. Their results showed that different plant communities responded differently to the amount of rainfall. Other studies had indicated that the growing season and spring rainfall were the most effective factors of rangeland production and vegetation cover of the species (Akbarzadeh *et al*., 2007; Lei and Peters, 2003; Persendt, 2009). The aim of this study is to determine the effective rain months in the forage production and vegetation cover of *Festuca ovina, Bromus tomentellus, Dactylis glomerata,* and *Agropyron trichophorum* and to create formulas using mathematical equations to estimate the forage production and cover for the long term.

Materials and Methods

The present study was performed in Polur region in Alborz Mountains, Mazandaran province, Iran. The map of site location is presented in Fig 1.

The climatic data including the annual rainfall, growing season rainfall, growing season plus previous year rainfall, growing season rainfall of March, annual mean temperature and growing season

temperature of region were collected from 2002 to 2006 and 2013 from Abali synoptic station. This station was the closest location to the site of study in terms of the quality and quantity of climatic information as well as distance.
The forage yield and vegetation cover were collected along six permanently marked transects with approximately 100 m intervals. Each transect had 200m length and 10 plots. The vegetation cover of 60 plots and the forage production of 15 plots were collected during the six years of 2002 to 2006 and 2013. The mean forage production and vegetation cover as well as the amount of rainfall and temperature data were recorded in Excel spreadsheet. The relationships between vegetation indices and climatic factors were assessed for each species using stepwise regression. In stepwise regression, the annual vegetation cover and forage production of each species were considered as dependent variables and six climatic variables as independent ones using SPSS19. The relationships between vegetation indices and the significant climatic variable were plotted by polynomial regression using Excel software.

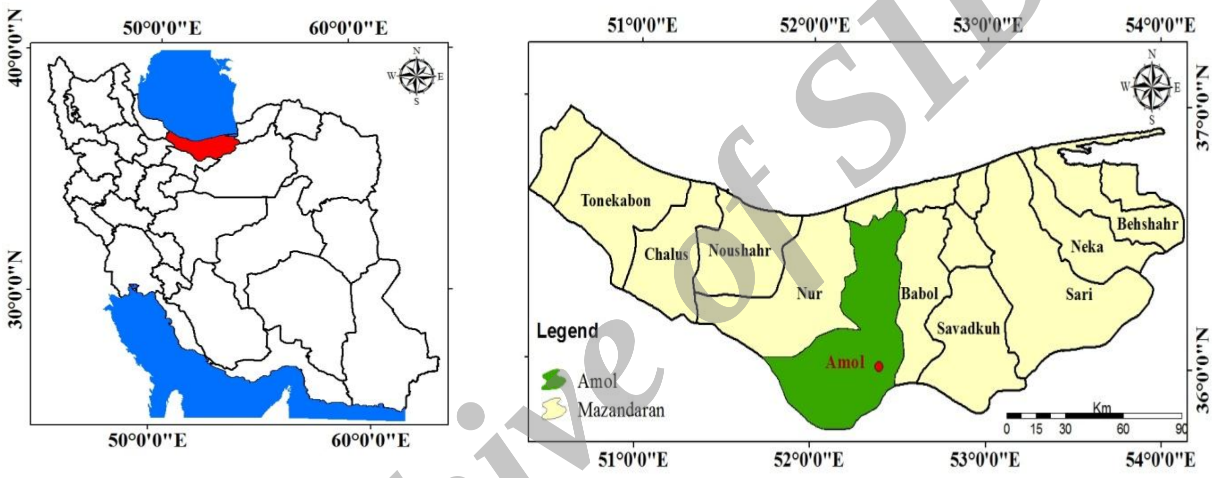

Fig.1. Map of location of study area

Results

The amounts of rainfall and temperature distribution in Abali synoptic station during 2002 to 2006 and 2013 are shown in Table 1.
The mean annual rainfall in the period of 2002-2006 and 2013 was 585.4 mm. The maximum rainfall was 717 mm that occurred in 2004, and the minimum rainfall was 456 mm that occurred in 2013. The mean annual temperature was 8.9°C. The maximum temperature mean in the growing season was 19.15°C that occurred in 2006 and the minimum was 17.7°C that occurred in 2002. The mean vegetation cover and forage production of *F. ovina, B.tomentellus, D.glomerata* and *A. trichophorum* are shown in Figs. 2 and 3, respectively. The results showed that the maximum vegetation cover and forage production were obtained in *A.trichophorum* as 17.8% and 184.18 kg/ha, respectively.

Table 1. The amount and distribution of studied climatic factors during 2002-2006 and 2013

Year	Annual rainfall (mm)	Growing season and previous year rainfall (mm)	March and growing season rainfall (mm)	Growing season rainfall (mm)	Growing season Temperature (mm)	Annual Temperature (mm)
2002	526.6	600	242.0	41.4	17.73	9.36
2003	717.9	587.3	363.7	60.7	18.10	8.50
2004	532.8	836.9	290.2	119.0	17.83	9.22
2005	641.9	638.9	293.7	106.1	18.05	8.03
2006	637.2	717.2	197.2	75.3	19.15	9.66
2013	456.2	702.2	135.4	65.0	18.30	9.15

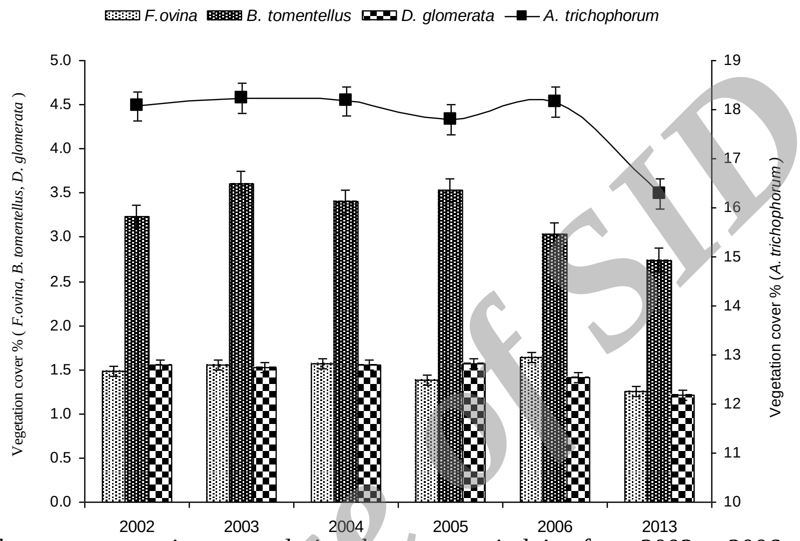

Fig. 2. The mean vegetation cover during the target period, i.e. from 2002 to 2006 and 2013

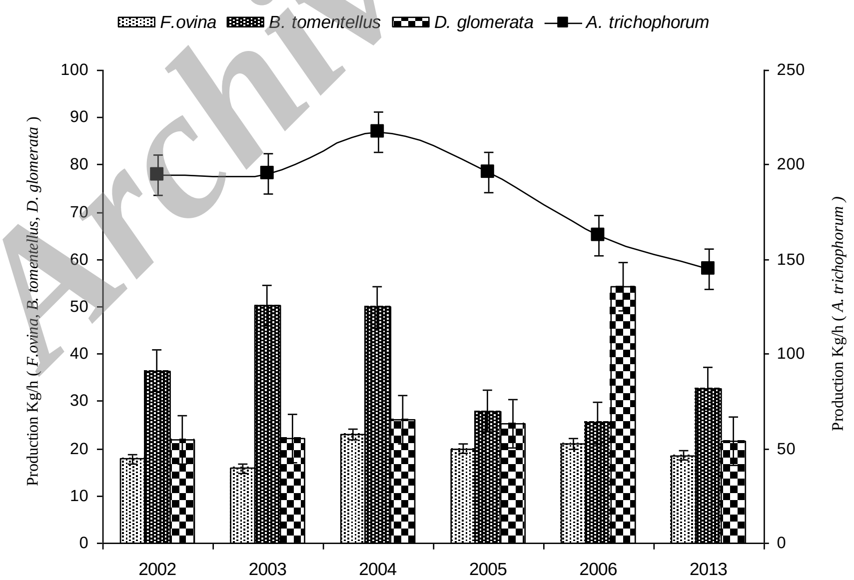

Fig. 3. Mean forage production (kg/h) in Polur during 2002 to 2006 and 2013

The results of stepwise regression of climatic independent variables, the forage production and vegetation cover of target species as dependent variables alongside the regression slop (b) and coefficient of determination (R^2) are presented in Table 2. In each tepwise regression, only one significant variable was entered in the final model (Table 2).

According to the results, the forage production of *B.tomentellus* and *A. trichophorum* was significantly affected by March plus growing season rainfall which explained 41 and 84% of the production variation, respectively. The forage production of *F. ovina* was significantly influenced by the growing season plus the previous year rainfall. For *D. glomerata*, there was no relationship between forage production and climatic variables (Table 2).

For vegetation cover, the growing season rainfall of March was the most effective index in *B. tomentellus*, *A. trichophorum* and *D. glomerata* with R^2 values of 95.58, 78.40 and 67.39, respectively (Table 2).

The correlations between effective climatic variables and both vegetation cover and forage rangeland production were assessed using polynomial Regression (Fig. 4). The relationships between the growing season rainfall of March with both vegetation cover and rangeland production were linear and quadratic in *B. tomentellus* and *A. trichophorum*, respectively (Fig 4). The relationships between the growing season and previous year rainfall and rangeland production and between the growing season rainfall of March and vegetation cover were linear and quadratic in *F. ovina* and *D. glomerata*, respectively (Fig 4).

Table 2. The results of stepwise regression of rainfall and temperature as independent variables and the forage production and vegetation cover of target species as dependent variables

Climatic Parameters	Species	Variables	Constant	Regression coef.	R^2
March and growing season rainfall	*B. tomentellus*	Production	15.76	0.084*	41.89
		Cover	2.248	0.0040**	95.58
	A.trichophorum	Production	178.4	0.411**	84.73
		Cover	8.071	0.0103*	78.40
	D. glomerata	Cover	1.11	0.0014*	67.39
Growing season and last year rainfall	*F. ovina*	Production	3.425	0.023*	74.88

*,** = regression coefficient (b) is significant at 5 and 1% probability levels.

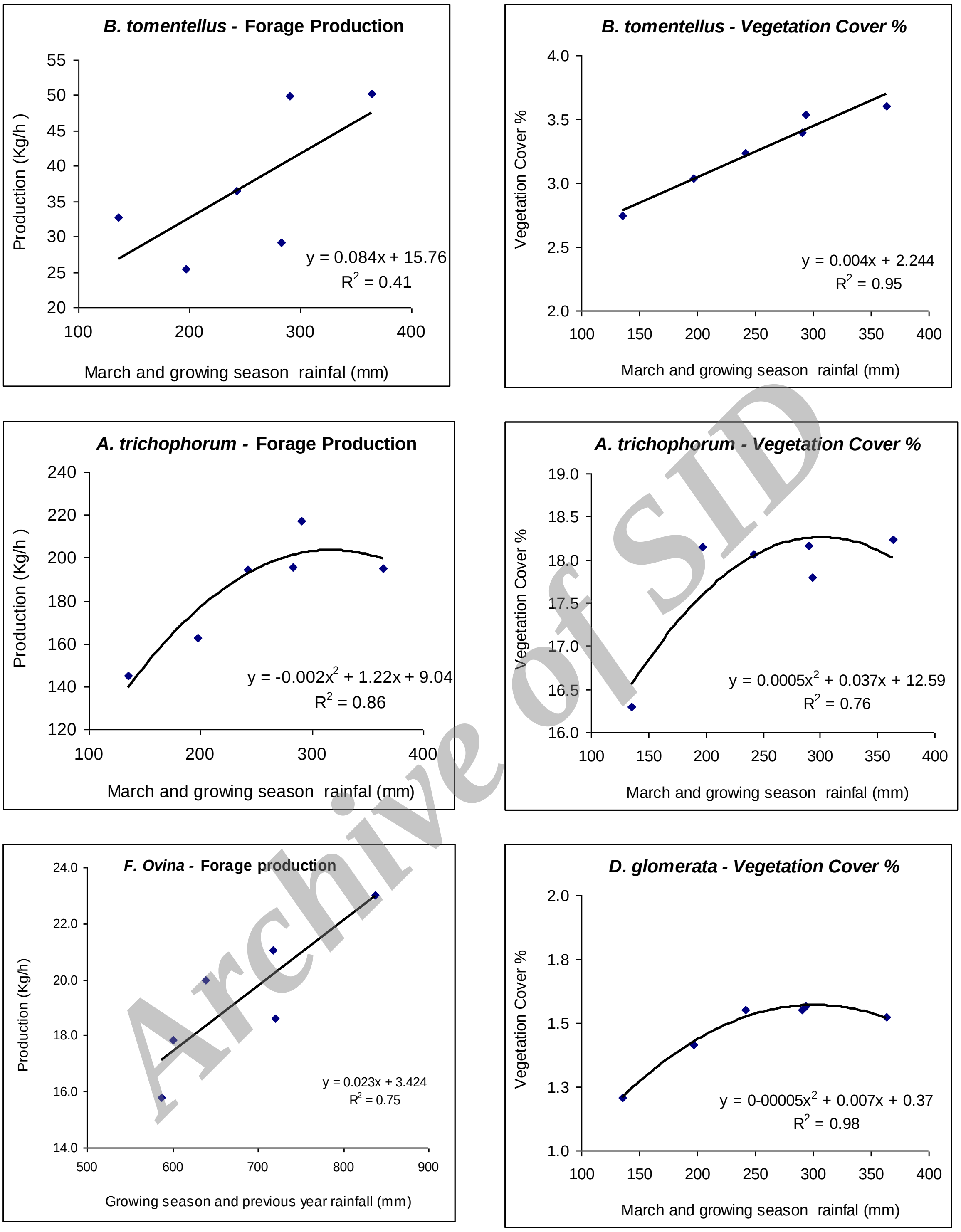

Fig. 4. Polynomial regression equations between growing season rainfall with vegetation cover and forage production in four grass species

Discussion

Vegetation cover and forage production change by rainfall and temperature in Polur. The amount of rainfall and its distribution will affect the vegetation cover and forage of the foregoing and future years. This effect was different in various species. Munkhtsetseg *et al*. (2007) state that it is always possible that period of high temperatures can limit plant growth without a significant reduction in the amount of rainfall.

Therefore, simultaneous investigation of rainfall and temperature is necessary. Learning about the impact of rainfall and temperature on vegetation indices fluctuations over a long period paves the way for necessary predictions and proceedings in the optimal management of rangelands. Based on the study, the mean forage production and vegetation cover in 2002-2006 and 2013 were 347.9 kg/ha and 49.6 percent, respectively. The highest vegetation cover and forage production of grassland were observed in 2004, and *A. trichophorum* had the maximum vegetation cover and forage production. In addition to good rainfall in 2004, the March rainfall, and the growing season plus the previous growing season rainfall had significant roles in the increase of forage and vegetation cover as shown in Table1 and Figs 2 and 3. The species of *B. tomentellus A. trichophorum,* and *D. glomerata* and vegetation covers were affected by the growing season rainfall of March. The regression equations showed that the growing season rainfall of March explained 95, 78 and 67% vegetation cover variations, respectively. Hosseni *et al.* (2001) found the effects of March and April rainfall as the most effective courses on alfalfa forage production. Also, Akbarzadeh *et al.* (2007) emphasizes the effective role of the growing season rainfall in grass forage production in the same area of Polur grassland. In agreement with our study, Mirjalili and Mousaee (2008) found high and significant correlations (r=0.96) and (r=0.99) between annual forage production with the annual rainfall and the growing season rainfall, respectively.

The results of 2013 showed that lower rainfall (465 mm) had the lowest forage production. The drought of 2013 decreased the *A. trichophorum* forage production and as a result, the rangeland forage production was declined. The March plus growing season rainfall affected the *A. trichophorum* forage production. In present study, there was no relationship between forage production and temperature. Ghaemi (2001) investigated some vegetation changes including canopy cover, density, forage production and rangeland conditions with emphasis on rainfall and temperature factors. His results showed that the total vegetation cover had a direct relationship with rainfall but a converse one with temperature. Excessive temperature hinders the plant photosynthesis process.

The best equation to estimate the *Festuca ovina* forage production can be proposed when the growing season and the previous year rainfall are used. Ehsani *et al*. (2007) investigated the effect of climate factors on forage production over an eight year period in Akhtarabad located in Saveh, 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 *B. tomentellus* and *A. trichophorum* based on the proposed equations had no significant correlation for the long-term period. We can estimate forage production based on the developed equation.

According to our results, the forage production of all the species except *D. glomerata* and vegetation cover of all the species except *F. ovina* can be estimated by rainfall data. However, the temperature data were not suggested to estimate forage production and vegetation cover. It seems that the reason is low fluctuation and similar data of temperature rather than rainfalls in the study area.

Conclusion

The rainfall is a suitable factor in the estimation of long-term forage production and vegetation cover because of a high correlation with them. The reaction of plants varies based on their growth form as well as the time and quality of rainfall. Therefore, with the knowledge of the effects of rainfall fluctuations on vegetation indices over a long period, it is possible to make the necessary predictions for the optimized management of rangelands, especially in the drought periods.

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تأثیر عوامل اقلیمی بر روی تاج پوشش و تولید علوفه چهار گونه گندمی مراتع نیمه‌استپی استان مازندران در ایران

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چکیده. بررسی تغییرات پوشش گیاهی و شناخت نحوه تبعیت این تغییرات از شرایط رطوبتی و بارندگی حاکم بر مرتع از مهمترین عواملی است که در تعیین سیستم برنامه‌ریزی صحیح جهت بهره برداری و مدیریت آن موثر است. تأثیر عوامل اقلیمی (بارندگی و دما) بر پوشش و تولید علوفه چهار گونه گندمی (*Agropyron trichophorum* ،*Dactylis glomerata* ،*Bromus tomentellus* ،*Festuca ovina*) در طی سالهای ۱۳۸۱ تا ۱۳۸۵ و سال ۱۳۹۲ در مراتع نیمه‌استپی استان مازندران (مرتع پلور) مورد بررسی قرار گرفت. شاخص‌های مهم اقلیمی شامل بارندگی سالانه، بارندگی فصل رویش، بارندگی فصل رویش بعلاوه سال ماقبل، بارندگی اسفند بعلاوه فصل رویش، میانگین درجه حرارت سالانه و درجه حرارت فصل رویش مورد بررسی قرار گرفتند. برای این منظور تعدادی پلات با پراکنش منظم انتخاب شد. داخل پلاتها تولید و پوشش اندازه گیری شد. رابطه بین پوشش و تولید علوفه و مقادیر بارش و دما بوسیله تجزیه رگرسیون گام به گام به تفکیک هر گونه در نرم‌افزارSPSS19 مورد تجزیه و تحلیل قرار گرفتند. نتایج نشان داد که گونه‌های گیاهی به نوسان‌های بارندگی واکنش نشان دادند. با این‌حال واکنش پوشش و تولید به نوسانهای بارندگی و درجه حرارت در گونه‌های مختلف متفاوت بود. از بین شاخص‌های مهم اقلیمی، بارندگی ماه اسفند و فصل رویش بعنوان مؤثرترین شاخص روی تولید و پوشش گونه‌های *A.trichophorum* و *B. tomentellus* و پوشش گونه *D.glomerata* اثرگذار بوده و همبستگی مثبت و معنی‌داری را نشان داد. تولید گونه *F. ovina* تحت تاثیر بارندگی فصل رویش و سال پیشین بود. بر طبق این نتایج، تولید گونه *Festuca ovina* به همراه پوشش *D.glomerata* و تولید و پوشش گونه‌های *B. tomentellus* و *A.trichophorum* براساس داده‌های بارش قابل برآورد می‌باشند. بنابراین با آگاهی از نحوه تأثیر بارندگی و دما بر نوسان شاخصهای گیاهی در یک دوره طولانی، می‌توان پیش‌بینی لازم را در جهت مدیریت بهینه عرصه‌های مرتعی به خصوص در مواقع خشکسالی اعمال نمود.

واژگان کلیدی: مرتع پلور، تولید علوفه، تاج پوشش، بارندگی، درجه حرارت