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Determinization of Environmental Factors Effects on Plants Production in QezelOzan-Kosar Rangelands, Ardabil Province Factors Effect on Rangelands Production

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ABSTRACT

Aims The aim of the present study was to determine the most important environmental factors affecting aboveground net primary production (ANPP) of plants along the altitude gradient in QezelOzan-Kosar rangelands, Iran.
Materials & Methods Eight sites along the altitude gradient were selected, in each of which three transects parallel and perpendicular to the slope were established. Along each transect (totally 240 plots), ANPP and soil samples were measured. Using digital elevation model (DEM) map, the maps of slope, aspect, elevation, topographic index (CTI), stream power index (SPI), plan curvature (PC), precipitation and temperature were extracted. The soil parameters measured in soil laboratory. To determine the important effective factors, principal component analysis (PCA) was used. Moreover, the ANPP prediction equation was simulated using the parameter which had the greatest impact and correlation with ANPP (precipitation), using 2nd-order polynomial model and mapped further.
Findings The results of PCA revealed that six components had the highest effect on the ANPP variations (76.35% of ANPP variations). The result of simulated equation and map indicated acceptable accuracy (R^2= 0.95, RMSE= 0.73).
Conclusion The results of the present study highlight the importance of topographic, climatic, and soil factors in ANPP variations, and can be used to manage QezelOzan-Kosar rangelands for establishing balance between biomass and carbon of the ecosystem and ecosystem supply and demand.

Keywords Rangelands; Biomass; Prediction Equation; Modeling

CITATION LINKS

[1] Relationships between environmental factors and ... [2] A vegetation index to estimate terrestrial gross primary ... [3] Disentangling the relationships between net primary ... [4] Drought-induced reduction in global terrestrial ... [5] Combing both simulated and field-measured data ... [6] Comparing global models of terrestrial net primary productivity ... [7] Heterogeneity of light use efficiency in a ... [8] Investigating the relationships between net primary production ... [9] Study the effects of elevation, slope and aspect on ... [10] Plant functional group composition modifies the ... [11] Meta-analysis of relationships between environmental ... [12] A comparison of the strength of biodiversity effects across multiple ... [13] Grazing impacts on the diversity and composition of alpine ... [14] Herbage response to precipitation in central Alberta boreal ... [15] Plant functional types and climate along ... [16] Pasture yield response to precipitation and high temperature ... [17]Effect of phosphorus supply on plant productivity, photosynthetic ... [18] Healing the planet: Strategies for resolving the environmental ... [19] Effects of temperature and rainfall on the aboveground net primary production of Hir and ... [20] Composition and structure of species along altitude gradient in Moghan-Sabalan rangelands ... [21] Ecological factors affecting the distribution ... [22] Digital terrain modelling: A review of hydrological ... [23] Data mining approaches for landslide susceptibility mapping in Umyeonsan ... [24] Notes and observations: Aspect transformation in site productivity ... [25] How to evaluate models: Observed ... [26] Spatial variation analysis of soil properties using spatial statistics ... [27] The effective factors of destruction in Kermanshah ... [28] Relative importance of climate changes at different ... [29] Effects of precipitation and temperature on net primary productivity ... [30] Effect of plant diversity on the diversity of soil organic ... [31] Effects of plant process on soil organic carbon ... [32] Moisture and soil parameters drive plant community ... [33] Relationships between Poshtkouh rangeland vegetative of Yazd ... [34] Effects of calcium and magnesium ... [35] Effects of topographic and edaphic characteristics ... [36] The global impact factors of net primary ... [37] Predicted NPP spatiotemporal variations ...

Introduction

Rangelands are major natural ecosystems in the world, and have also an important role in protein production and balancing ecosystems [1]. More than 5.3 billion ha of rangelands exist in the world, of which 903 million ha are located in Asia (excluding the Middle East) while the rangelands of the Middle East cover 303 million ha, of which 86.1 million ha belongs to Iran [1]. These ecosystems constitute major sinks in the global carbon cycle [2]. Their net primary production (NPP) represents the main energy input into terrestrial ecosystems [3] and determines the: i) atmospheric carbon amount fixed by plants, and ii) aggregated biomass [4], which is a critical environmental factor in global climate change and terrestrial ecosystems [5]. In the cycle of terrestrial carbon, gross primary productivity (GPP), NPP, and heterotrophic respiration as well as their corresponding geographical and seasonal variations are key components [6]. One of the important processes of ecosystems is NPP, the difference between GPP and autotrophic respiration, as it removes carbon dioxide from the atmosphere and stores it in short-lived (foliage and fine roots) and long-lived (wood) tissues [7]. Many physicochemical factors influence the ANPP of plant species. One of the most important factors in ANPP changes is topographic factors (such as elevation above sea level, slope, and aspect of a domain) [8, 9]. Also, the changes in precipitation essentially affect the structure and functioning of terrestrial ecosystems [10]. Large-scale regional studies have explained the effects of climatic factors (precipitation and temperature) on ANPP or aboveground biomass in ecosystems, especially in grasslands [11]. The reason is that availability of water and temperature changes is the primary limiting factor for plant growth and community composition in ecosystems [11]. Thus, understanding how ANPP of ecosystems respond to precipitation and temperature is essential in assessing the effects of global changes on terrestrial ecosystems. In addition, different soil parameters heavily influence ANPP changes [12].

Without a historical record of rangeland productivity, differences in ANPP cannot be precisely quantified [13]. Thus, several studies have documented that ANPP is determined by environmental factors such as temperature, precipitation, sunlight, soil properties, and CO_2 concentration in the air [4]. In a study in central Alberta, authors studied the herbage response to precipitation in boreal grasslands and reported a significant relationship between the production of rangeland and precipitation [14]. In another study, in north-east China and south-east Mongolia the plant functional types and climate along precipitation and temperate gradient in grasslands were studied and reported that there was a positive correlation between grasses growth and precipitation [15]. In a study in Mongolia, the yield of rangelands response to climatic factors was studied and reported the high temperature of July along with diminished precipitation levels in June as the main factor in production changes [16]. In another study, the phosphorus effect on plant productivity changes was studied and revealed a significant relationship between these two factors [17]. In the study in Sabalan rangelands of Ardabil Province, the effects of elevation, slope, and aspect on life form forage production changes were studied and reported a significant relationship between topographic factors and production of Sabalan rangelands [9]. In a study in Hir-Neur rangelands of Ardabil Province, researchers investigated the relationship between ANPP and topographic factors and reported a significant relationship between these factors [8]. In the present study, the prediction map of rangeland production was prepared using 2nd-order polynomial model.

The QezelOzan-Kosar region contains remarkable rangelands at the northwest of Iran whose vegetation communities care loosely related to other cold areas in northwest of Iran. This calibration could be a useful tool for managers of natural resources and ecologists since providing an easy method for estimating rangeland production as one further step to gain more precise results. Due to the effective environmental factors in changes of plants' communities [18], the specific goals were: i) determining the most important environmental factors in ANPP changes; ii) modeling the ANPP prediction equation and, iii) simulating the ANPP map using prediction equation.

Materials and Methods

Study area

Kosar County, with the centrality of Givi City in Ardabil Province, Iran, has an area of approximately 1245Km^2 (Figure 1). The coordinates of the study area are 37°41′16″ N to 37°41′58″ N and from 48°22′42″ E to 48°23′25″

E. The minimum and maximum elevation above sea level are 837 and 2350m, respectively (Figure 1). The main source of the precipitation in the area is moisture of the Mediterranean Sea, from October to May. Further, the mean annual temperature of nearest station (Khalkhal) is 8.7°C. The soils of these lands are shallow to semi-deep, with rocky mode. In the study area, sheep, goat, and other livestock constitute more than 95%, less than 3%, and 2% of the livestock composition, respectively. The grazing season in rangelands is from May to November. Generally, 8 vegetation types have been reported: 1) Astragalus; 2) Astragalus-Thymus; 3) Trifolium-Lolium; 4) Astragalus-grasses; 5) Astragalus-Artemisia; 6) Thin forest; 7) Meadow, and 8) Trifolium-Perennial grasses.

Field sampling

To conduct this study, according to the access road, eight sites were selected (Figure 1). The characteristics of each site are reported in Table 1 and Figure 2. In each site, three transects perpendicular to the slope and parallel to each other were established with 50m distance of each other, according to the vegetation structure and related studies [8, 19-21]. The method of sampling was random-systematic. Along each transect, 10 plots with a distance of 10m from each other (30 plots in each site) were placed. At the time of maximum growth, ANPP was estimated using one square plot through clipping and weighing (harvesting) method (240 plots). The size and number of plots were determined according to the vegetation structure and number of samples required as well as previous studies [19-21]. Field sampling was conducted in June 2017. The position of each plot was recorded with global position system (GPS).

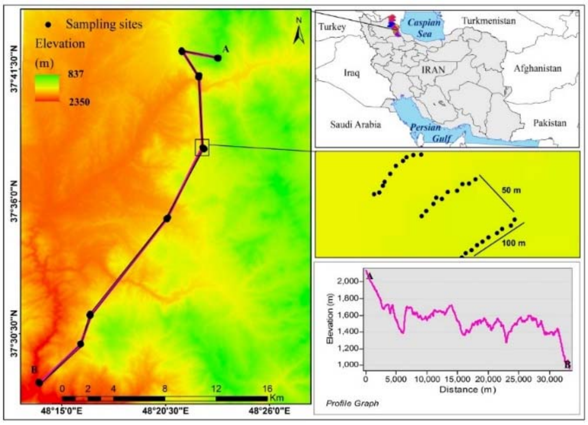

Figure 1) Location of the study area in Ardabil Province, Iran

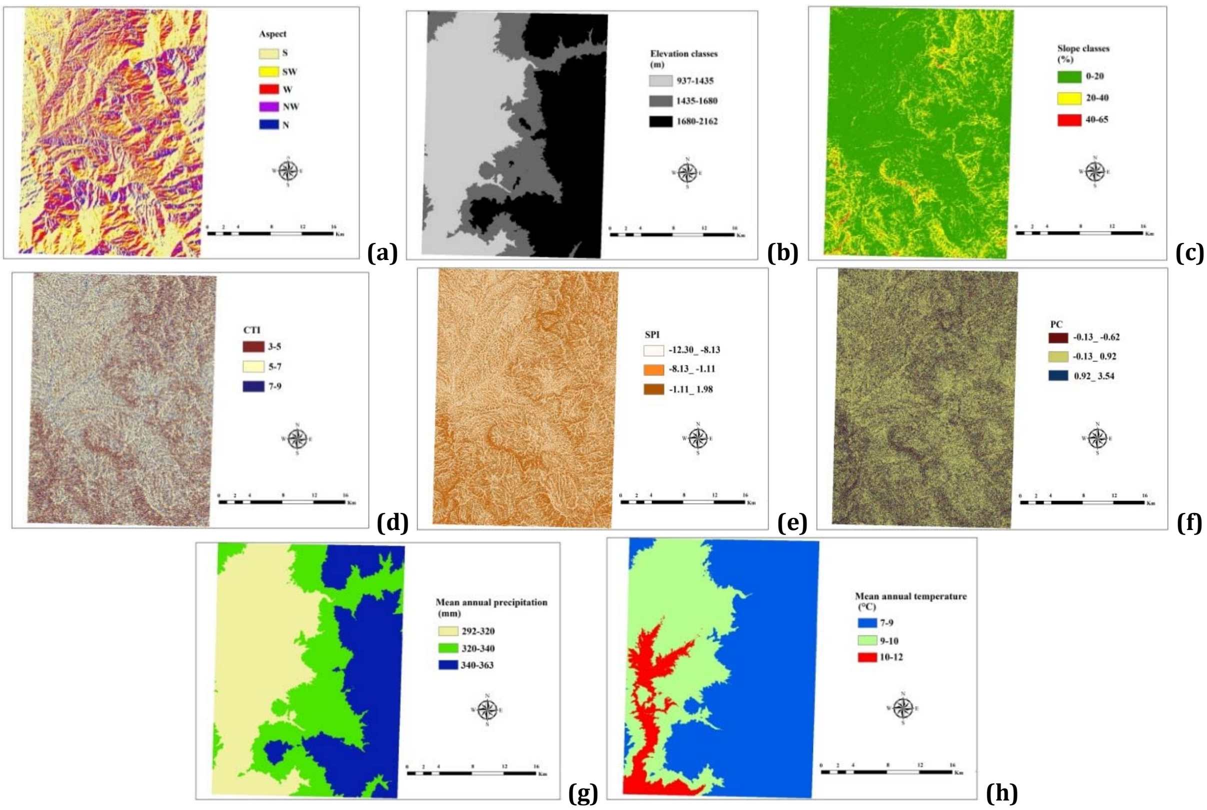

Figure 2) Maps of environmental factors of the study area, Elevation (a); Aspect (b); CTI (c); Slope (d); PC (e); SPI (f); Temperature (g); Precipitation (h)

Table 1) Description of sampling sites at QezelOzan-Kosar rangelands

Variable mean	Sites							
	1	2	3	4	5	6	7	8
X, Y	37 50° N 48 26° E	37 47° N 48 23° E	37 52° N 48 27° E	37 59° N 48 33° E	37 64° N 48 36° E	37 69° N 48 36° E	37 70°N 48 37°E	37 70° N 48 34° E
Elevation (m)	952	1490	1590	1417	1653	1521	1663	2149
Slope (%)	21	15	22	9	18	17	15	9
CTI	5.11	6.55	5.58	6.5	6.53	6.14	5.07	5.75
SPI	-3.37	-2.08	-2.22	-4.97	-4.92	-1.91	-6.06	-6.18
PC	0.26	0.08	0.02	-0.07	0.09	-0.49	0.37	0.15
Aspect	SW	W	NW	W	N	S	N	S
Annual precipitation (mm)	293	322	328	320	334	327	336	362
Annual temperature (°C)	11	10	9	10	9	9	9	7
Clay (%)	42.50	42.36	30.03	41.80	47.66	24.30	28.20	26.20
Mg (mg/lit)	10.20	6.96	8.26	8.10	9.06	8.73	12.83	11.86
Silt (%)	34.00	27.46	35.43	33.73	29.50	33.30	44.10	40.70
P (ppm)	24.73	26.55	24.54	21.44	20.00	21.27	19.45	18.02
CaCo3 (%)	7.06	10.10	8.40	15.26	7.36	11.70	8.93	2.06
pH	7.82	7.80	7.73	8.03	7.75	7.94	7.98	7.93
Na (mg/kg)	26.67	12.33	12.33	29.67	29.00	23.67	14.67	15.00
EC (ds/m)	0.33	0.22	0.28	0.36	0.27	0.37	0.27	0.53
K (mg/kg)	55.67	71.67	61.67	67.33	80.67	76.67	79.83	95.00
Ca (mg/lit)	52.76	32.36	28.33	38.76	33.13	41.43	25.93	48.90
Sand (%)	23.50	30.20	34.53	24.46	22.83	42.40	27.70	33.10
N (%)	0.10	0.09	0.12	0.10	0.11	0.11	0.12	0.23
OC (%)	0.75	0.71	0.89	0.78	0.77	0.80	0.90	1.74
Grasses ANPP (kg/ha)	51	179	245	186	122	85	129	134
Forbs ANPP (kg/ha)	438	165	364	199	480	360	335	362
Shrubs ANPP (kg/ha)	252	29	83	58	168	1	126	183
Total ANPP (kg/ha)	741	373	692	443	770	446	590	679

Maps preparing

DEM map of the study area was created using 1:25000 maps of Iranian mapping agency with pixel size of 20×20m. The maps of elevation, slope, aspect, compound topographic index (CTI), stream power index (SPI), and plan curvature (PC) were created using DEM map (Figure 2). In addition, using gradient equations (calculated from the study areas stations), the precipitation and temperature maps were extracted, and the value of maps was extracted for each plot position (each GPS). The CTI index map was created using Equation 1. In this map, low-value areas indicated small basins with a high slope while high-value areas indicated big basins with a low slope [22].

$$CTI= Ln\ (a/\tan \beta) \quad (1)$$

Where a is the magnitude of accumulation of upstream flow and β represents the slope of the domain.

SPI estimates the erosion power of a stream, which affects the stability of the area. Therefore, it is generally used to determine the locations for performing soil conservation measures to reduce the erosive effects of concentrated surface runoff. SPI can be calculated as follows [22]:

$$SPI= As \times \tan\ (b) \quad (2)$$

Where As is the area of the target part of the study area and b shows the slope angle.

PC values of the terrain surface were calculated using the curvature tool in GIS. The curvature represents the morphological characteristics of the study area. An upwardly convex surface possesses a positive value, while an upwardly concave surface has a negative value [23].

The aspect data were transformed to numerical style using Equation 3 [24]. Also, climatic data (precipitation and temperature) were extracted for each GPS point (plot) using the gradient. The sampled soils (mixed soil samples of 1, 5, and 10 plots in each transect) were sent to soil laboratory where parameters of Ca, CaCo3, clay, EC, K, Mg, N, Na, OC, P, pH, sand, and silt were measured.

$$A' = \cos\ (45-A)+1 \quad (3)$$

Where A′ is the value of the converted direction and A represents the value of the azimuth of the direction.

Statistical analysis

According to the aim of study, in order to determine the justification and the common effects of the different factors, correlation test was used for factors of elevation, slope, aspect, CTI, SPI, PC, annual temperature (mean of 25 year, 2016 and 2017), annual precipitation (mean of 25 year, 2016 and 2017), soil parameters (sand, P, K, Mg, $CaCo_3$, N, silt, OC, clay, Na, EC, and pH), and the factors with a correlation greater than 0.8 removed from the dataset (Climatic data were collected from the Kosar weather station and stations of around the area. Using climatic data, temperature and precipitation gradients equations were prepared for the QezelOzan-Kosar rangeland, for each plot position (GPS points). Moreover, for each transect, a mixture of soil samples was taken from the first, fifth, and tenth plots and its parameters were evaluated in the soil laboratory). Then, to determine the percentage of the effect of each environmental factor on ANPP, the principal component analysis (PCA) was used. The parameter with the greatest impact and correlation with ANPP was selected, and 2^{nd}-order polynomial model was used to extract the predictive ANPP equation. The general equation of 2^{nd}-order polynomial model as Equation 4. Where Y was the dependent factor, a, b_1, and b_2 represent coefficients and x is the independent factor. Using modeled equation and base map, the ANPP map was simulated. Assessment of the accuracy of ANPP map was performed by criteria of root mean squared error (RMSE), mean absolute error (MAE), and mean deviation error (MDE; Equations 5, 6, and 7, respectively). Where Esi is simulated ANPP map, Eoi shows the measured ANPP of field, and n represents the number of data [25, 26]. Generally, 80% of data were used for analysis and 20% were for the accuracy assessment [19, 26]. Analysis of data was performed by SPSS 22.0, MATLAB R2018a, and PC-ORD 5.0 software. The maps were modeled and produced using ArcGIS 10.0 ESRI 1999-2010.

$$\mathrm{Y} = \mathrm{a} + \mathrm{b}_1\mathrm{x}^2 + \mathrm{b}_2\mathrm{x} \quad (4)$$

$$\mathrm{RMSE} = \frac{\sqrt{\sum_{i=1}^{n}(Esi - Eoi)^2}}{n-1} \quad (5)$$

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n}|\mathrm{Esi} - \mathrm{Eoi}|}{\mathrm{n}} \quad (6)$$

$$\mathrm{MDE} = \frac{\sum_{i=1}^{n}(\mathrm{Esi} - \mathrm{Eoi})}{\mathrm{n}} \quad (7)$$

Findings

From 149 identified species, 16.77% of species were grasses (25 species), 77.18% were forbs (115 species), and 6.05% were shrubs (9 species). Moreover, based on the mean total ANPP value (592kg/ha), 23.82% were grasses ANPP (mean of 141kg/ha), 57.09% were forbs ANPP (mean of 338kg/ha), and 19.09% were shrubs ANPP (mean of 113kg/ha).

PCA results on the effects of environmental factors on ANPP variations revealed that the eigenvalues of the first to sixth components were maximum for BSE indicator (Table 2). Therefore, these six components were identified for justifying the changes of ANPP. The first to sixth components accounted for ANPP changes of 27.85%, 11.98%, 11.73%, 9.80%, 8.43%, and 6.55%, respectively. In general, these six components are responsible for 76.35% of the ANPP changes.

Table 2) Eigenvalue and variance of each axis with PCA method

Axis	Eigenvalue	Variance (%)	Cumulative (%)	BSE
1	5.85	27.85	27.85	3.64
2	2.64	11.98	39.83	2.51
3	2.46	11.73	51.56	2.14
4	2.05	9.80	61.36	1.81
5	1.77	8.43	69.80	1.56
6	1.37	6.55	76.35	1.36

Table 3 shows the vector eigenvalues of variables in the components. According to coefficients and significance, the annual precipitation and temperature, elevation, OC, and N were selected in the first component. The sand, Ca and K in the second component, the CTI and EC in the third component, the Na and PC in the fourth component, the pH, SPI, CaCo3, P, slope, and aspect in the fifth component, and finally the factors of silt, Mg and clay in the sixth component. Therefore, these factors were identified as the most effective environmental factors on the ANPP changes.

Table 3) Component matrix based on affective environmental factors

Environmental factors	Components					
	1	2	3	4	5	6
Annual precipitation	0.371	-0.134	0.002	-0.096	0.076	**-0.221**
Annual temperature	-0.368	0.134	-0.002	0.098	-0.085	**0.235**
Elevation	0.368	-0.131	0.002	-0.102	0.091	**-0.242**
OC	0.347	0.244	-0.106	0.060	0.014	**-0.001**
N	0.341	0.259	-0.119	0.056	0.016	**-0.002**
Sand	0.110	0.453	0.113	-0.336	-0.084	**-0.093**
Ca	0.041	0.377	-0.274	0.294	-0.023	**0.190**
K	0.288	-0.313	-0.053	0.127	0.049	**-0.019**
CTI	-0.011	-0.164	-0.437	-0.280	0.148	**0.110**
EC	0.245	0.182	-0.307	0.145	-0.072	**0.231**
Na	-0.104	0.004	-0.348	0.391	-0.008	**0.063**
PC	0.017	-0.045	0.277	0.358	-0.259	**-0.157**
pH	0.039	-0.116	-0.270	-0.117	-0.537	**-0.008**
SPI	-0.132	0.000	-0.248	-0.352	0.401	**0.181**
$CaCo_3$	-0.197	-0.140	-0.159	-0.278	-0.347	**-0.136**
P	-0.144	0.275	-0.117	-0.150	-0.295	**-0.249**
Slope	-0.176	0.212	0.289	-0.020	0.294	**0.015**
Aspect	-0.055	0.061	-0.144	0.088	0.278	**-0.127**
Silt	0.086	-0.345	0.080	-0.009	-0.116	**0.540**
Mg	0.176	0.051	0.285	-0.003	-0.066	**0.391**
Clay	-0.181	-0.175	-0.180	0.346	0.179	**-0.346**

Diagram 1 represents the categorization of environmental factors affecting ANPP changes, based on the first and second components. The points of Diagram in justifying the causes of spatial distribution of environmental units and ANPP changes were noticeable. The farther the points were away from the origin of the coordinates and closer to a particular axis or component, the more they were affected by it. Also, in the interpretation of this Diagram, the algebraic sign of correlation coefficients between the characteristics and the components was considered. Based on the positive and negative variable coefficients in Table 3, in the first component, the elevation has a direct relationship with precipitation and an inverse relationship with temperature. In the second component, Ca and sand had a direct relationship with each other. Also, Table 1 data can be considered the most important influential factors in each sampling site. There were 30 plots in each site (plots 1 to 240 in eight sites). The characteristics of each site are presented in Table 1 for recognition of the area's characteristics.

Considering the results of the 2nd-order polynomial model, it was observed that mean annual precipitation was most effective in the changes of ANPP. Considering the significant level of this factor in predicting ANPP, ANPP can be calculated using Equation 8.

$$ANPP_{(Kg/ha)} = -(1.996\ Precipitation^2)+(1324\ Precipitation)-218950 \quad R^2= 0.95 \qquad (8)$$

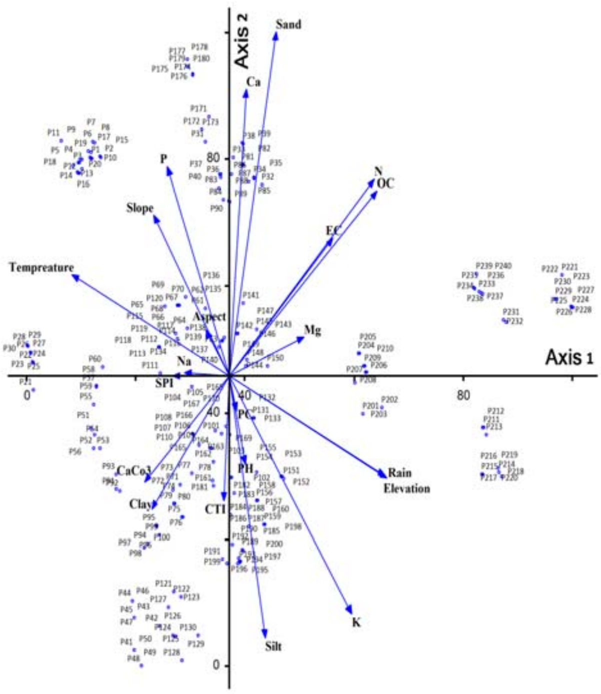

Diagram 1) PCA graph based on components 1 and 2 and plots with effective environmental factors (P1-240: Plots number)

The simulated ANPP map using the equation and base map is presented in Figure 3. According to the map, the ANPP varies between zero and

800kg/ha. In 1.47% of the study region, the ANPP was 0-200kg/ha. In 8.70% of the study region, the ANPP varied from 200-400kg/ha. In 49.39% of the study region, the ANPP lied within the range of 400-600kg/ha. Finally, in 40.44% of the study region, the ANPP was 600-800kg/ha.

The accuracy of the simulated equation and ANPP map was evaluated using RMSE, MAE, and MDE criteria, with the average ANPP obtained from the prepared map and the average ANPP measured according to Table 6. Given the MAE and MDE values, the results are acceptable. Further, the RMSE value or model error value is also acceptable indicating the validity of the model (Table 4). In addition, Diagram 2 reveals the correlation between the measured and estimated ANPP scatter plots.

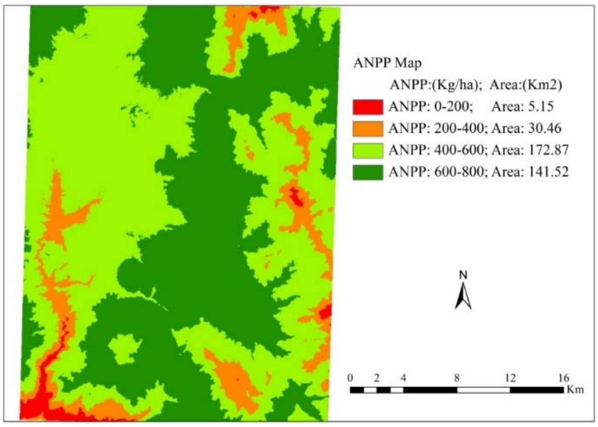

Figure 3) Simulated ANPP map based on 2^{nd}-order polynomial equation

Table 4) Accuracy assessment of simulated ANPP map based on regression equation

Factor	ANPP
Mean of collected ANPP (kg/ha)	529.41±34.47
Mean of simulated ANPP map (kg/ha)	527.17±51.36
MAE	0.88
MDE	0.94
RMSE	0.73

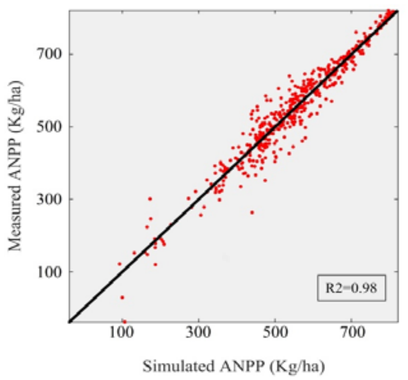

Diagram 2) Goodness of fit scatter plot between measured and simulated ANPP

Discussion

According to the results of PCA, 76.35% of the ANPP changes in the QezelOzen-Kosar rangelands was influenced by environmental factors (topography, climatic, and soil). The remaining percentage can be affected by various factors such as utilization rate, grazing, degradation of vegetation cover, and many other factors. In a study in Kermanshah rangelands, researchers also emphasized the changes and degradation of vegetation cover due to grazing, thereby altering the ANPP [27].

The results of PCA indicated that the first component, which includes precipitation, temperature, elevation above sea level, OC and N of soil, had the maximum impact (27.85%) on ANPP. The reason for the high importance of elevation on the ANPP changes can be climate change, where the temperature drops and precipitation grows with increasing elevation. These results are consistent with the findings of a study in the field of ANPP and topographic factors relationship in Hir-Neur rangelands [8]. They reported that among the different factors, elevation was the most important factor in ANPP changes. Considering the altitude changes that lead to climate change and due to the ecological response of different plants relative to the amount of precipitation and temperature, the climatic factors along with the elevation are likely to be the most important factors in the ANPP changes, which is similar to results of other studies. In various studies in China rangelands, authors identified elevation and climatic factors as the most important factors in ANPP changes [28, 29]. Other influential factors were OC which had a significant effect on the storage of water and food and thus soil fertility. Indeed, one of the reasons for the ANPP changes can be the extent of soil fertility. This is in line with the results of various studies in the field of soil properties [30, 31]. They reported that there is a significant relationship between soil OC and rangeland plant growth. Another important and effective factor in the ANPP change is N. The variations of this parameter which can be influenced by climatic and topographic factors drive changes in soil moisture in different locations. The results of this part of the present study are congruent with the results of a study, suggesting that soil moisture is the most important factor in changes of vegetation characteristics [32].

Following the mentioned factors, the second component had the most influence on the ANPP changes of the study area. This component involves the sand, Ca, and K. Among these factors, sand is related to soil texture, where the ability to absorb water, minerals, and soil porosity in various soil textures is different. Also, different plants may respond to different types of soil texture. This is in line with the results of other studies about soil properties in Yazd Province [33]. They reported soil texture as one of the most important factors in the changes of plant characteristics such as ANPP. Another important factor in this component is Ca. Specifically, in a study, also identified Ca as one of the most important factors in plant growth [34]. Concerning the third component, EC and CTI accounted for 11.73% of the changes in ANPP. The CTI changes also alter the area and slope of the basin causing variations in the absorption which maintains the soil moisture [22], culminating in ANPP alteration. With regards to the fourth component, Na and PC explained 9.80% of ANPP changes. Na might change the soil properties including soil pH, which, as stated earlier, exhibit different reactions to different soil properties. This part of the results is congruent with the results of a study in Eshtehard rangelands [35]. The PC represents the morphological and topographic characteristics of the study region [23]. Changes of this index of plant can have different effects on ANPP.

The fifth component includes pH, SPI, CaCo3, P, slope, and aspect. Soil pH is one of the most important factors which can influence the needs of different plants to acidic and alkaline soils due to the presence of limestone and acidic substances. Moreover, the adsorption and solubility of soil elements and nutrients are affected by soil pH whose elevation usually reduces the solubility of nutrients, resulting in altered ANPP. In this regard, the results are similar to the findings of a study in Eshtehard rangelands, which identified pH as one of the most important factors affecting vegetation changes in rangelands [35]. Further, SPI with erosive effects of runoff in rangelands [22] can also influence ANPP. CaCo3 probably affects the nutrient matter of soil and cause changes in plant characteristics. The slope is also one of the most important factors in the ANPP variations. With the elevation of slope, grazing power declines, and definitely the extent of water absorption in high slope areas also drops. This part of the results is in line with the studies of Sabalan and Hir-Neur rangelands, who introduced the slope as one the most important factors in ANPP changes [8, 9]. Also, aspect, influenced by moisture and angle of sun, causes ANPP changes. In a study in Hir-Neur rangelands, researchers also reported this result [8]. Finally, silt, Mg, and clay were included in the sixth component. Among these factors, soil parameters (P, Mg, and EC) were investigated by various studies [34-36]. There are also important factors involved in the changes of ANPP and plant characteristics, where the results are similar to those of the present study.

For modeling the prediction equation of the study region ANPP, 2nd-order polynomial model was used between ANPP collected data and annual precipitation, which indicated a significant relationship. According to the results of PCA, such a result was not expected. Using the modeled prediction equation from the 2nd-order polynomial model, ANPP map was simulated in ArcGIS, whose accuracy assessment was acceptable. This part of the results also corresponded to the results of various studies, who reported this methodology as the best method in evaluation of climatic and topographic factors on plant production in Sabalan and Hir-Neur Rangelands [8, 9, 19]. The modeling method presented in this study could uniquely capture the rangeland ANPP across the area. Therefore, the mentioned feature plays an important role in the choice of an appropriate factor depending on the regional characteristics. Note that both of the methods (PCA and polynomial model) were used to find the most effective factors, though they had differences with each other. In this study, the PCA was used to determine the percentage of each factor's effect on production changes. The polynomial model was utilized to derive the ANPP prediction equation as well as to prepare the ANPP map. It is suggested as the aim of the study was to investigate the effects of topographic, climatic, and soil factors on ANPP, other factors such as grazing intensity should also be taken into account for better management of rangelands [37].

Conclusion

The results of the present study can produce a sustainable human-ecological management policy with enhancing ecosystem services and management to balance the biomass in rangelands. In addition, the results highlight that further studies are required to consider comprehensive factors (such as degradation, grazing, and exploitation) to clarify the mechanisms of ANPP changes.

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