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Original Research Article

Modeling canopy cover and aboveground net primary production using soil factors in rangelands of Ardabil province, Iran

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***Abstract*:** Canopy cover (CC) and the aboveground net primary production (ANPP) vary under the influence of various environmental factors. They underscore ecological sustainability under different environment-human interactions. Towards this, the present study aimed to model the CC and ANPP of different plant functional types (PFTs) and their total using the soil attributes in the northwest (Ardabil province) rangelands of Iran. According to ecoregions and plant types and environmental factors, sampling was taken at the peak stage of plant growth from 2016 to 2020 using 1-m2 plots. For each transect, a soil sample was taken and transferred to the soil laboratory and the various attributes were measured. Maps of soil attributes were prepared using the inverse distance weighting (IDW) method. Differences in CC and ANPP of PFTs among soil attributes were analyzed using the paired sample t-test. Linear multiple regression was used for modeling the soil attributes. Total CC and ANPP were prepared in two ways (i.e., regression and PFTs maps summing). The accuracy assessment of the maps was calculated by using the criteria of mean absolute error (MAE), mean deviation error (MDE), and root mean squared error (RMSE). The obtained results were acceptable (value < 7). The difference between the modeled and measured mean values of CC was equal to –0.03% for grasses, –0.01% for forbs, +0.03% for shrubs, 0% for $\text{total}_{\text{regression model}}$, and +0.06 for $\text{total}_{\text{PFTs maps summing}}$. Additionally, this difference in terms of the ANPP was equal to 0 kg/ha for grasses, +0.02 kg/ha for forbs, –0.09 kg/ha for shrubs, –0.02 for $\text{total}_{\text{regression model}}$, and +0.02 kg/ha for $\text{total}_{\text{PFTs maps summing}}$. The present results are applicable to managing the balance between supply and demand of rangeland products and they can be used from carbon management perspectives.

Keywords: Forecasting; Soil and Plant Attributes; Plant Functional Types; Ardabil Ecoregions

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1. Introduction

Proper rangeland management is based on ecological principles and understanding its processes is one of the important preconditions to reach successfully this purpose. It is important to understand the relationship between ecological factors in nature, including topography, climate, soil, vegetation factors, and living organisms[1]. One of the solutions in range land management is modeling the ecosystem by various environmental factors which will lead to better management of the future status of rangelands, especially in arid and semi-arid regions[2]. Due to the fact that chemical parameters of the soil change under the influence of direct and indirect effects of topographic and climatic factors, thus the mentioned factors have major effects on plant communities[3]. Different soil properties, including physical and chemical, have an effective role in changing rangelands and vegetation characteristics such as canopy cover (CC) and aboveground net primary production (ANPP), and on the other hand, vegetation has an effective role in soil change and development[4,5]. Therefore, the simultaneous study of plant and environmental factors can have better results.

Significant studies have been conducted on the relationship between soil and vegetation, especially the diversity and distribution of plant species. For example, Naves *et al*.[6] studied soil properties and topographic factors on the growth and distribution of plants in central Spain. They reported that EC, soil moisture, and pH were the most important factors affecting plants. Abdolzadeh *et al*.[7] also noted that different species showed different behaviors to the amount of soil phosphorus (P). Rocarpian *et al*.[8] studied the effect of soil moisture on plant changes in Mediterranean regions and they found a direct relationship between them. In addition, El Mojahid *et al*.[9] studied the relationship between soil organic carbon (OC), and vegetation characteristics and recorded a significant relationship (p-value < 0.01) between the mentioned factors as well as species richness.

Zare Chahouki *et al*.[10] investigated the effect of topographic and soil factors on plant species in the Eshtehard rangelands of Iran. Among the soil factors, texture, lime, and EC were the most important factors affecting the vegetation of the region. Shokrollahi *et al*.[1] assessed the effects of soil properties and physiographic factors on vegetation in Pleur summer rangelands of Iran. The soil texture, P, pH, OC, and electrical conductivity (EC) have been recognized as the most important factors influencing vegetation changes.

As it can be seen from the literature review, the relationship between soil with CC and ANPP of natural ecosystems has received less attention and research. For example, Thomey *et al*.[11] examined the relationship between NPP, rainfall, and soil factors in Chihuahuan desert grassland. There was a significant relationship (p-value < 0.01) between soil moisture and NPP. Yu *et al*.[12] also examined the relationship between NPP with soil P. There was a significant relationship (p-value < 0.01) between P changes and NPP. Recently, Ghorbani *et al*.[3] considered the modeling of biomass by soil factors in the Hir-Neur Rangelands of Iran. They reported that among the measured soil factors, the silt, EC, calcium (Ca), potassium (K) soluble, OC, particulate organic carbon (POC), pH, magnesium (Mg), total neutralizing value (TNV), clay, P, and moisture had the highest effect in the biomass forecast.

The relationship between CC and ANPP with climatic factors[13] and topography[14] has been considered, as well. By examining the literature, it has

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been determined that few studies have been conducted on the relationship between soil properties with CC and ANPP. The authors believe that the soil factors are among the most influential factors in the changes of CC and ANPP; the authors' main decision was to determine the effect of soil factors. Rangelands of Ardabil province are among the significant rangelands in Iran and there is limited knowledge about the amount of CC and ANPP, as well as factors affecting their changes. The aim of this study, therefore, was to model the CC and ANPP of plant functional types (PFTs) and their total with soil attributes. It is expected that the results of this research will be applicable to establish a balance between the supply and demand of rangeland ecosystems. In addition, appropriate basic information to create a carbon balance state in the ecosystem could be provided.

2. Materials and methods

2.1 Study area

The study area was the rangelands of Ardabil province located in northwestern Iran with geographical coordinates of 37°45' to 39°42' N and 47°20' to 48°55' E (**Figure 1**). According to the digital elevation model (DEM), the minimum and maximum elevations are 14 and 4,811 m, respectively.

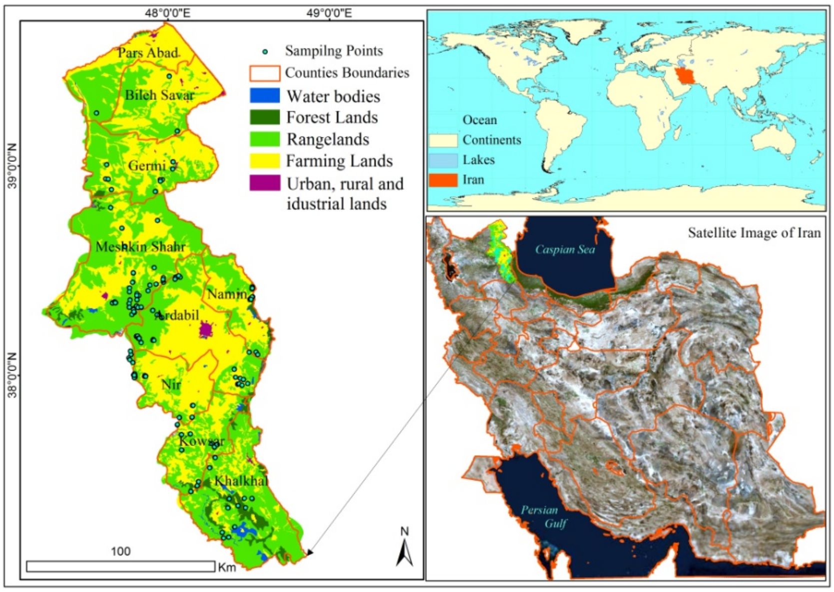

Figure 1. Location of sampling points, sites, and study area in Ardabil province, Iran.

Table 1. Land use types of Ardabil province

Land use	Area (ha)	Area (%)
Farming lands	770,071.80	43.81
Forest lands	7,845.30	0.45
Rangelands	947,259.00	53.89
Urban, rural and industrial lands	30,320.20	1.72
Water bodies	2,322.00	0.13
Total	1,757,818.30	100

Moisture inflows between four and eight months from early October to May are the main source of rainfall in the region, which enters the country after crossing the Mediterranean Sea and enriching with water vapor. The wettest season occurs in winter with 37% annual rainfall and the driest season occurs in summer with 2.7% annual rainfall.

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Based on the obtained information from the 25-year data of meteorological stations in the study area (including all counties of Ardabil province), the average minimum and maximum annual rainfall are 245 and 527 mm. The average minimum and maximum annual temperatures are 1.34 and 15.88 °C[13]. The land use types of the province are presented in **Table 1**[15]. According to the collected plant data, the highest percentage of species belonged to forbs (62%), and grasses (18%), shrubs (14%), and trees have the lowest (6%) percentage. More than 95% of the province's livestock is formed from sheep and less than 5% included other animals[14,16–18].

2.2 Research method and sampling

According to the access road, sampling sites were determined throughout the rangelands of Ardabil province (**Figure 1**). At each site, three transects were determined at a distance of 50 m from each other. The location of the first transect was random, and the next transects were systematically deployed perpendicular to the slope direction in the representative areas. Along each transect, 10 plots of 1-m^2 (30 plots in each site) were placed at intervals of 10 m from each other; then estimation of the CC and ANPP of PFTs was done using reticulated plots and clipping/weighing, respectively. However, soil samples were collected from the beginning, middle, and end of the plots at each transect from 0–15 cm depths and mixed together as representative of each transect. Dimensions and the number of plots were determined according to the vegetation structure and the number of required samples as well as previous studies[18–20]. Due to the vastness of the study area, field operations were carried out during the growing season in different years from 2016 to 2020 in the form of six M.Sc. theses[21–26] and two Ph.D. dissertations[19,20] throughout the rangelands of ecological regions of Ardabil province. The position of plots was also recorded for analysis and modeling using the Global Positioning System (GPS).

2.3 Soil laboratory analysis

Soil samples were dried and then sieved to 2 mm before analysis in the laboratory of the University of Mohaghegh Ardabili. Soil factors were analyzed for OC (loss on ignition), nitrogen content (N/Kjeldahl method), P (P-Olsen method)[27], EC (EC meter "soil-water ratio of 1:1"), Ca (Titration EDTA)[28], Mg (Titration EDTA)[28], organic matter (OM), volumetric humidity (VU), and sand, silt, and clay as a soil texture (hydrometer method)[29].

According to **Figure 2**, maps of each soil factors were prepared using the interpolation method of inverse distance weighting (IDW) by using ArcMap. This method of interpolation estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell.

2.4 Data analysis

The normality of data was examined using the Kolmogorov–Smirnov test[30]. Differences in CC and ANPP of PFTs between soil attribute classes were analyzed using the paired sample t-test. Linear multiple regression (Equation 1) was used for modeling the soil factors and CC as well as ANPP.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_nx_n \quad (1)$$

where, Y is the dependent variable, a is the constant value, b is the regression coefficient, and x is the independent variable.

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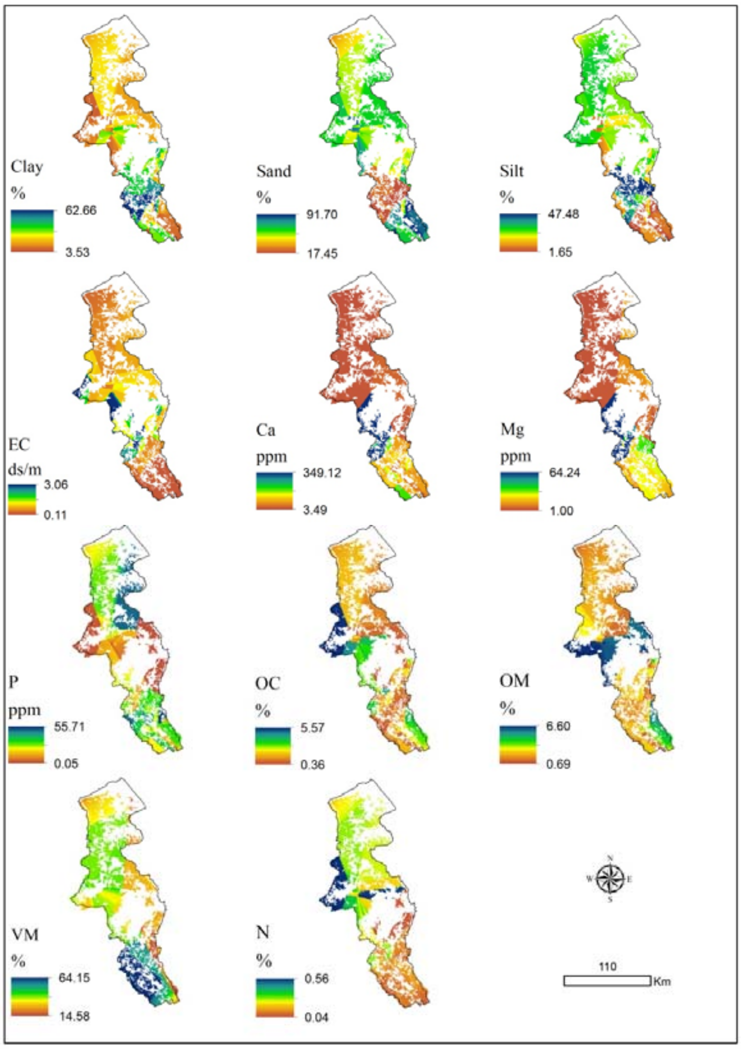

Figure 2. The interpolated maps of soil factors.

Total CC and ANPP were prepared in two ways (i.e., regression, and PFTs maps summing). The accuracy of the equations was also calculated by MAE, MDE, and RMSE (Equations 2, 3, and 4, respectively). A total of 85% and 15% of the data were used for map modeling and accuracy assessments, respectively. Statistical analysis and mapping were performed with $SPSS_{ver22.0}$, and $ArcGIS_{ver10.0}$ software, respectively.

$$MAE = (\Sigma^{n}_{i=1} \left| Es_i - Eo_i \right|)/n \quad (2)$$

$$MDE = (\Sigma^{n}_{i=1}(Es_i - Eo_i))/n \quad (3)$$

$$RMSE = (\sqrt{\Sigma^{n}_{i=1}(Es_i - Eo_i)^2})/n\text{-}1 \quad (4)$$

where, Es_i was the estimated values of the maps, Eo_i was the measured at the field, and n was the number of data points.

3. Results

3.1 Mean comparison of plant attributes

The results of paired sample t-test showed that CC and ANPP of PFTs and the total had a significant relationship with soil factors. For example, grasses CC is 17.89% in lower classes of clay (3.97%–32.70%), and this amount is equal to 11.99% in higher classes of clay (32.71%–61.44%). Thus, CC

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and ANPP of PFTs had a direct relationship with sand, EC, Ca, Mg, OC, OM, and N factors. Also, CC and ANPP of PFTs had an inverse relationship with clay, silt, P, and VM factors (**Table 2**).

Table 2. Mean comparison of CC and ANPP of PFTs and total at classes of soil factors

Soil factors	Classes	CC Mean (%)				ANPP Mean (Kg/ha)			
		Grasses	Forbs	Shrubs	Total	Grasses	Forbs	Shrubs	Total
Clay (%)	3.97–32.70	17.89 ± 0.18	21.45 ± 0.13	9.95 ± 0.11	56.25 ± 0.56	530.52 ± 7.70	531.71 ± 6.61	200.06 ± 2.80	1,626.09 ± 22.33
	32.71–61.44	11.99 ± 0.14	16.99 ± 0.10	6.22 ± 0.09	37.95 ± 0.44	281.46 ± 6.07	317.71 ± 5.21	109.29 ± 2.21	903.82 ± 17.61
Sand (%)	20.54–55.60	14.33 ± 0.11	18.76 ± 0.08	7.70 ± 0.07	45.19 ± 0.36	380.04 ± 4.99	402.41 ± 4.29	145.21 ± 1.82	1,189.69 ± 14.48
	55.61–90.67	15.02 ± 0.15	19.28 ± 0.11	8.13 ± 0.09	47.33 ± 0.48	409.09 ± 6.61	427.37 ± 5.68	155.80 ± 2.41	1,273.95 ± 19.19
Silt (%)	1.65–23.26	17.22 ± 0.14	20.94 ± 0.10	9.53 ± 0.09	54.16 ± 0.45	502.16 ± 6.14	507.34 ± 5.27	189.72 ± 2.23	1,543.85 ± 17.81
	23.27–44.87	13.77 ± 0.11	18.34 ± 0.08	7.35 ± 0.07	43.48 ± 0.34	356.71 ± 4.68	382.36 ± 4.02	136.71 ± 1.70	1,122.04 ± 13.58
EC (ds/m)	0.14–1.40	13.60 ± 0.21	18.21 ± 0.15	7.24 ± 0.13	42.95 ± 0.65	349.54 ± 8.91	376.21 ± 7.65	134.10 ± 3.24	1,101.25 ± 25.84
	1.41–2.67	19.54 ± 0.11	22.70 ± 0.08	11.00 ± 0.07	61.37 ± 0.34	600.32 ± 4.70	591.67 ± 4.04	225.49 ± 1.71	1,828.49 ± 13.63
Ca (ppm)	4.75–156.67	9.67 ± 0.31	15.24 ± 0.23	4.75 ± 0.19	30.75 ± 0.97	183.49 ± 13.25	233.53 ± 11.38	73.59 ± 4.82	619.71 ± 38.43
	156.68–308.60	14.56 ± 0.16	19.00 ± 0.12	7.90 ± 0.10	46.19 ± 0.50	393.67 ± 6.87	414.12 ± 5.90	150.18 ± 2.50	1,229.22 ± 19.93
Mg (ppm)	1.31–28.30	9.34 ± 0.40	14.99 ± 0.30	4.54 ± 0.25	29.71 ± 1.24	169.36 ± 16.96	221.40 ± 14.57	68.44 ± 6.18	578.75 ± 49.18
	28.31–55.30	15.37 ± 0.17	19.55 ± 0.13	8.36 ± 0.10	48.43 ± 0.53	424.11 ± 7.32	440.28 ± 6.29	161.28 ± 2.66	1,317.51 ± 21.24
P (ppm)	0.08–21.54	15.89 ± 0.09	19.94 ± 0.06	8.69 ± 0.05	50.05 ± 0.28	446.16 ± 3.82	459.22 ± 3.28	169.31 ± 1.39	1,381.44 ± 11.08
	21.55–43.00	12.90 ± 0.18	17.68 ± 0.13	6.80 ± 0.11	40.78 ± 0.56	319.95 ± 7.75	350.78 ± 6.66	123.32 ± 2.82	1,015.44 ± 22.48
OC (%)	0.48–2.13	12.68 ± 0.09	17.51 ± 0.06	6.65 ± 0.05	40.07 ± .0.28	310.39 ± 3.84	342.57 ± 3.30	119.83 ± 1.40	987.72 ± 11.14
	2.14–3.79	18.72 ± 0.08	22.08 ± 0.06	10.48 ± 0.05	58.83 ± 0.26	565.74 ± 3.66	561.96 ± 3.15	212.89 ± 1.33	1,728.21 ± 10.63
OM (%)	0.86–3.68	12.75 ± 0.10	17.57 ± 0.07	6.70 ± 0.06	40.30 ± 0.31	313.41 ± 4.25	345.16 ± 3.65	120.93 ± 1.55	996.46 ± 12.35
	3.69–6.54	19.04 ± 0.07	22.31 ± 0.05	10.68 ± 0.04	59.80 ± 0.23	578.87 ± 3.19	573.24 ± 2.74	217.67 ± 1.16	1,766.29 ± 9.27
VM (%)	23.56–43.57	16.12 ± 0.12	20.11 ± 0.09	8.83 ± 0.38	50.74 ± 0.38	445.55 ± 5.21	467.29 ± 4.48	172.73 ± 1.90	1,408.67 ± 15.12
	43.58–63.59	13.82 ± 0.13	18.37 ± 0.09	7.37 ± 0.08	43.60 ± 0.40	358.43 ± 5.48	383.85 ± 4.71	137.34 ± 2.00	1,127.04 ± 15.91
N (%)	0.06–0.20	14.39 ± 0.10	18.81 ± 0.08	7.74 ± 0.06	45.40 ± 0.32	382.83 ± 4.48	404.81 ± 3.85	146.23 ± 1.63	1,197.79 ± 13.01
	0.21–0.47	16.35 ± 0.16	20.28 ± 0.12	8.97 ± 0.10	51.46 ± 0.50	465.35 ± 6.86	475.71 ± 5.89	176.30 ± 2.50	1,437.10 ± 19.89

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3.2 Modeling

The range of factors for Durbin-Watson's statistic was between 1.5 and 2.5. Also, VIF was within the permissible limit. The predictive equations using a linear multiple regression model based on soil factors with PFTs and total CC and ANPP were created (Equations 5 to 12).

Grasses CC = – (6.89 × N) – (0.02 × VM) + (0.77 × OM) + (0.87 × OC) – (0.05 × P) + (0.24 × Mg) – (0.04 × Ca) + (1.27 × EC) – (0.06 × Silt) – (0.01 × Sand) – (0.03 × Clay) + 15.65	R^2 = 0.84	p-value < 0.01	(5)
Forbs CC = – (5.20 × N) – (0.02 × VM) + (0.58 × OM) + (0.66 × OC) – (0.03 × P) + (0.18 × Mg) – (0.03 × Ca) + (0.96 × EC) – (0.04 × Silt) – (0.008 × Sand) – (0.02 × Clay) + 19.75	R^2 = 0.86	p-value < 0.01	(6)
Shrubs CC = – (4.36 × N) – (0.01 × VM) + (0.49 × OM) + (0.55 × OC) – (0.03 × P) + (0.15 × Mg) – (0.03 × Ca) + (0.80 × EC) – (0.03 × Silt) – (0.006 × Sand) – (0.02 × Clay) + 8.53	R^2 = 0.87	p-value < 0.01	(7)
Total CC = – (21.38 × N) – (0.08 × VM) + (2.40 × OM) + (2.72 × OC) – (0.15 × P) + (0.76 × Mg) – (0.14 × Ca) + (3.96 × EC) – (0.18 × Silt) – (0.03 × Sand) – (0.09 × Clay) + 47.28	R^2 = 0.83	p-value < 0.01	(8)
Grasses ANPP = – (291.10 × N) – (1.12 × VM) + (32.75 × OM) + (37.06 × OC) – (2.13 × P) + (10.46 × Mg) – (2.01 × Ca) + (53.91 × EC) – (2.55 × Silt) – (0.42 × Sand) – (1.31 × Clay) + 435.73	R^2 = 0.81	p-value < 0.01	(9)
Forbs ANPP = – (250.12 × N) – (0.96 × VM) + (28.14 × OM) + (31.85 × OC) – (1.83 × P) + (8.99 × Mg) – (1.72 × Ca) + (46.32 × EC) – (2.19 × Silt) – (0.36 × Sand) – (1.12 × Clay) + 450.26	R^2 = 0.80	p-value < 0.01	(10)
Shrubs ANPP = – (106.08 × N) – (0.41 × VM) + (11.93 × OM) + (13.50 × OC) – (0.77 × P) + (3.81 × Mg) – (0.73 × Ca) + (19.64 × EC) – (0.93 × Silt) – (0.15 × Sand) – (0.47 × Clay) + 165.51	R^2 = 0.82	p-value < 0.01	(11)
Total ANPP = – (844.19 × N) – (3.26 × VM) + (94.99 × OM) + (107.49 × OC) – (6.19 × P) + (30.36 × Mg) – (5.82 × Ca) + (156.33 × EC) – (7.41 × Silt) – (1.23 × Sand) – (3.80 × Clay) + 1,201.19	R^2 = 0.81	p-value < 0.01	(12)

3.3 Modeling of maps

The estimated PFTs and total CC and ANPP were mapped for the study area (**Figure 3**). Mapping was done with the base maps (interpolated soil maps) and the raster calculator of ArcMap. The CC values for grasses were between 8% to 24%, forbs CC was in a range between 14% and 26%, shrubs CC was between 4% to 14%, $Total_{regression\ model}$ CC was between 26% to 73%, and $Total_{PFTs\ maps\ summing}$ CC was between 26% to 64%. Moreover, the ANPP values of grasses were between 147 to 785 kg/ha, forbs were a range between 202 and 750 kg/ha, shrubs ANPP was between 56 to 289 kg/ha, $Total_{regression\ model}$ ANPP was between 363 to 2,214 kg/ha, and $Total_{PFTs\ maps\ summing}$ ANPP was between 405 to 1,824 kg/ha.

3.4 Accuracy assessment

The measured (field data) vs. estimated CC and ANPP values (image-derived estimations) were determined. The results of accuracy assessment/cross-validation based on the MAE, MDE, and RMSE criteria were acceptable (**Table 3**). Moreover, the results of the estimated CC and ANPP total values ($total_{Model}$) were more accurate than the sum of CC and ANPP from PFTs ($total_{Sum\ of\ PFTs}$).

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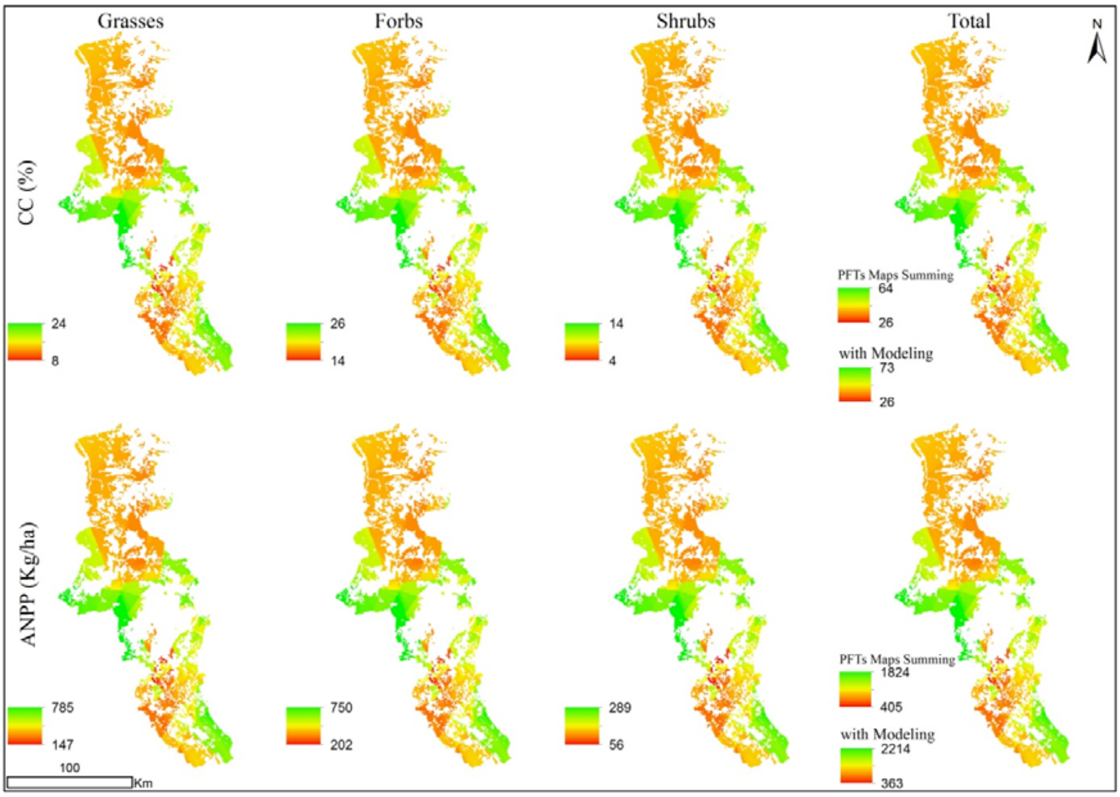

Figure 3. Modeled maps of plant attributes.

Table 3. Results of accuracy assessment

Plant attributes	PFTs	Measured mean	Estimated mean	Difference between estimated and measured	MAE	MDE	RMSE
CC (%)	Grasses	14.60	14.57	–0.03	1.55	1.24	0.33
	Forbs	20.66	20.65	–0.01	1.17	0.92	0.25
	Shrubs	9.43	9.46	+0.03	0.96	0.74	0.20
	$Total_{Model}$	44.63	44.63	0.00	2.16	–1.34	0.45
	$Total_{Sum\ of\ PFTs}$	44.63	44.69	+0.06	3.88	2.85	0.13
ANPP (Kg/ha)	Grasses	380.70	380.70	0.00	2.06	1.33	1.75
	Forbs	420.35	420.37	+0.02	2.26	1.53	1.77
	Shrubs	176.99	176.97	–0.09	2.90	0.83	1.84
	$Total_{Model}$	977.25	997.23	–0.02	3.20	0.73	1.85
	$Total_{Sum\ of\ PFTs}$	977.25	997.27	+0.02	6.53	–2.60	3.91

Note: + and – respectively indicate values more and less than the measured value.

4. Discussion

The results of comparing the mean of the t-test (**Table 2**) showed a significant difference in CC, and ANPP of PFTs between soil factor classes in different sites. Thus, the CC and ANPP of PFTs and total were directly related to sand, EC, Ca, Mg, OC, OM, and N factors; and inversely related to clay, silt, P, and VM factors. This can be influenced by the different needs of plants for adaptation and growth. These results were consistent with the results of Ghorbani *et al*.[3] who reported a significant relationship between ANPP with the silt, EC, Ca, K, OC, POC, pH, Mg, TNV, clay, P, and VM factors in Hir-Neur rangelands of Iran.

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Moreover, these results were consistent with the results of Griffiths *et al.*[31] and Thomey *et al.*[11] who reported significant differences between ANPP and soil factors. Since the sampling sites were different in terms of landforms and topography, it is expected that most changes in soil factors are affected by changes in elevation and, consequently, climate, including rainfall. This could point to the indirect effects of climatic, and topography factors, which were consistent with the results of Dadjou *et al.*[18].

According to the modeled equations for estimation of CC and ANPP of PFTs and total, it was observed that a high percentage of changes can be estimated by soil factors, but to obtain more appropriate relationships, it is necessary to study various factors of topographic, climate, and grazing intensity[32]. According to the models, it was observed that factors of N, VM, OM, OC, P, Mg, Ca, EC, silt, sand, and clay had a high correlation with CC and ANPP of PFTs and total. Changes in these soil factors can be influenced by the soil ingredients, kicking by livestock, animal waste in different places, and the amount of soil moisture, which is consistent with the results of Ghorbani *et al.*[3]. They reported the mentioned factors as the most important factors affecting vegetation factors.

Soil texture is one of the determinants of soil behaviour against water that absorbs it, flows as a runoff, evaporates water in the soil, or retains moisture, which in turn causes changes in CC and ANPP. Soil EC is also directly related to soil solutes. This factor affects leaf development and dry matter production, and so affects CC and ANPP. Another important and effective factor in CC and ANPP changes is soil VM, the changes of which can be influenced by climatic and topographic factors that are consistent with Sun and Du's[33] results. Given that most PFTs of grasses and forbs have surface roots, thus these results were not unexpected. Moreover, compaction, porosity, and texture of the soil can cause the absorption or non-absorption of water and ultimately cause changes in soil VM and changes in the amount of CC and ANPP. The results of this part of the study are consistent with Rocarpian *et al.*[8]. They have introduced soil VM as one of the most important factors in plant attribute changes.

Soil OC was obtained as an effective factor in CC and ANPP changes which was also introduced by Li *et al.*[34]. Increasing grazing intensity is likely to reduce nitrogen and thus lead to a reduction in OM and carbon storage, which in turn reduces CC and ANPP. Therefore, changes in grazing intensity can lead to changes in soil OC and consequently changes in plant attributes. OC also changes under temperature and rainfall variation. It was also observed that soil P, Ca, and Mg are influential factors in CC and ANPP changes, which was proved by Yu *et al.*[12]. P is one of the main elements needed by the plants. It is involved in all biochemical processes, energy compounds, and energy transfer mechanisms. In addition, P is responsible for plant reproduction and growth processes. Ca and Mg are also due to the decomposition of constituents and are the most important substances in changes in plant growth and development. These two factors also have many changes due to leaching. In this study, total CC and ANPP maps were prepared in two ways; i) by model and ii) by the sum of PFTs maps. The accuracy of the maps obtained in both methods was acceptable. These results were consistent with Ghorbani *et al.*[16].

5. Conclusion

To achieve better management, it is necessary to predict the CC and ANPP for the coming years. Of course, according to past studies, the authors believe that in order to achieve better results from the future CC and ANPP, climatic factors should be used. Nevertheless, the ambiguities of prediction by soil factors should also be resolved, and the present study was conducted with this aim. In the present study,

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modeling of CC and ANPP of PFTs and total were performed by soil factors for one-year data and, the results were acceptable. The results of this study showed that the modeling can be obtained in a short time to obtain a precise estimate of the whole area of CC and ANPP. Given that rangelands will be affected by environmental factors, it is, therefore, necessary to anticipate CC and ANPP to deal with stresses and manage carbon balance as well as the balance between the supply and demand of rangeland products.

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Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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