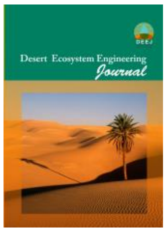
DEEJ (2023) 12 (9) 1-14

University of Kashan

Desert Ecosystem Engineering Journal

Journal homepage: http://deej.kashanu.ac.ir



Determining the Relationship between NDVI/Leaf Area Index and Plant Production in Vegetation Cover Studies using Remote Sensing

Afsaneh Afzali[1]*, Fatemeh Hadian[2], Leila Yaghmaei[2], Hossein Vahidi[3]

Received: 12/09/2022 Accepted: 19/03/2023

Abstract

Plant production is one of the most important living elements in ecosystems for example in the food cycle. In arid and desert areas, due to the fragility of these ecosystems, vegetation cover is of particular importance in reducing wind and water erosion. Therefore, the main purpose of this study is to study vegetation cover and plant production in desert and semi-desert climates of Khuzestan as a coastal province. In this study, while separating climatic classes, vegetation type and determining the status of rangeland, the relationship between vegetation cover, plant production, and NDVI/ Leaf Area Index (MODIS image products with the resolution of 250*250 m^2) in the separated layers of vegetation was calculated. The results showed that among the studied climates, the relationship between vegetation cover and satellite images decreases in semi-arid, arid, and ultra-arid climates, respectively, and in a climatic classification with vegetation type degradation, the relationship between vegetation and NDVI index weakens. The amount of leaf area index in this research was between 0.13 to 0.002, and *Quercus brantii* and *Scirpus* spp. showed the highest and lowest values, respectively. A comparison of the relationship between plant production and leaf area index shows that this relationship is stronger in the leaf area index than plant production as the main factor of plant production. Therefore, considering the importance of plant reflectivity, remote sensing studies and reduction of leaf area index, dry conditions and destruction of plant types can be the main reasons for reducing the relationship between vegetation and NDVI index.

Keywords: LAI, Plant production, NDVI, MODIS, Climate.

1. Department of Environment, Faculty of Natural Resources and Earth Sciences, University of Kashan, Kashan, Iran
2. Department of Natural Resources, Isfahan University of Technology, Isfahan, Iran, a.afzali@kashanu.ac.ir
3. Department of Environment, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran

DOI: 10.22052/JDEE.2023.248303.1082

1. Introduction

The management of rangelands and forests as the most important national assets is important due to their many uses. Recognizing and evaluating as well as monitoring changes in forest and rangeland habitats is critical to the management of these ecosystems. In addition, the response of natural ecosystems to climatic and managerial factors are among the factors that highlight the need for regular monitoring of natural areas (Hadian et al., 2014). The net primary production is strongly influenced by the vegetation structure which regulates the local meteorological conditions (Zheng and Moskal, 2009). Therefore, the appropriate land management strategy can be considered by observing the pattern of the leaf area index (LAI) in the ecosystems (Ma et al. 2014, Qiao et al., 2019). Leaf area is an important ecological and biological indicator (Pourhashemi et al., 2011; Tan et al., 2020) through which the exchange of energy between the earth's surface and the atmosphere is done (Majasalmi et al 2013). The soil quality improvement is affected by the leaf production added to the soil (Hadian et al., 2019; Ghorbani et al., 2020). Direct and indirect methods can be used for estimating LAI and have been compared in some studies (Fang et al. 2019; Yan et al., 2019). Direct methods called destructive methods evaluate the LAI, reliably. Direct methods are based on separating the leaves from the plant using the tools, such as surveyors in small plants (Singh and Singh, 2019). Despite the need for regular monitoring of natural areas, the vastness of rangelands and forests, and the high cost of assessing these ecosystems, as well as the existence of difficult-to-pass areas, are among the issues that make their study difficult (Nowruzi et al., 2013; Moeser et al., 2014). Therefore, using indirect methods such as regression models (Adl, 2007; Moeser et al., 2014), aerial photographs [Hosseini et al., 2013] and satellite images through remote sensing (RS) (Nowruzi et al., 2013) have been considered for estimating LAI. RS assists in studying and monitoring the ecosystems at a lower cost than field methods. The basis of remote sensing is the absorb, scatter, or transmit of different amounts of radiation at different wavelengths. The proportion of radiation that is reflected is considered as the spectral characteristics of various objects, including the plant. It is necessary to know and differentiate plant communities and to be aware of the spectral characteristics of plants and their slight differences. In the study of plants with the help of satellite images using bands and their different spectral compositions, plant indices are calculated and used for their evaluation and monitoring (Hadian, 2019). Changes in the canopy of plants change the way they are reflected in the spectrum (Blanco and Folegatti, 2003).

The environmental, climatic, and phenological conditions affect the LAI estimates which have been reported in some studies (Liu et al. 2012, Meng et al. 2020). The canopy reflectance and differences in plant performance also affect spatiotemporal variations. Besides, plant physiology, morphology, or anatomy defines its spectral properties (Thenkabail et al., 2000, Jarocinska et al., 2016). LAI can be estimated using different vegetation indices such as Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), and Normalized Difference Vegetation Index (NDVI) (Qiao, 2019). However, vegetation cover, plant production, and vegetation segregation can be widely estimated using NDVI. Above-ground plants in dry conditions but not under-ground production is considered as plant production in this study. Some studies have used vegetation indices for estimating LAI. Zarineh et al. (2012) in Tang-e Sayad natural park, Chahar-mahal and Bakhtiari, Iran evaluated different vegetation indices to study the vegetation canopy with the help of satellite images. They concluded that the NDVI index was suitable for studying the entire vegetation of the region to calculate rangeland production and determine wildlife capacity. Asadi et al. (2018) showed high accuracy of spectral vegetation indices for the estimation of winter wheat LAI in Mashhad, Iran. Behbahani et al. (2010) determined the vegetation cover percentage of single trees in arid woody rangelands of Iran using vegetation indices. They showed a stronger statistical correlation between NDVI and MSAVI, and the crown cover area compared to other indices. Goswami et al. (2015) presented a very high correlation of NDVI with production and LAI for six key species in Alaska. Lovynska et al. (2018) used direct and indirect methods for estimating LAI in Scottish pine trees of northern Ukraine. They showed a higher LAI obtained by the direct method than the value calculated by the indirect method, while its amount was not considerable (8.8% on average). Mani et al. (2017) showed that there was a positive relationship between terrestrial data and the NIR spectral reflectance band for the LAI of teak trees in India, while there was an inverse relationship with the red band. Khuzestan province includes different climate types from humid to ultra-arid ones. The main purpose of this research is to study the vegetation cover with the help of measuring the production and leaf area index in different types of plants in Khuzestan province by considering the conditions of the vegetation cover with the help of determining the condition of the rangeland. It should be also mentioned that the correlation between the LAI and plant production has rarely been investigated in previous studies which are considered the strength of this study.

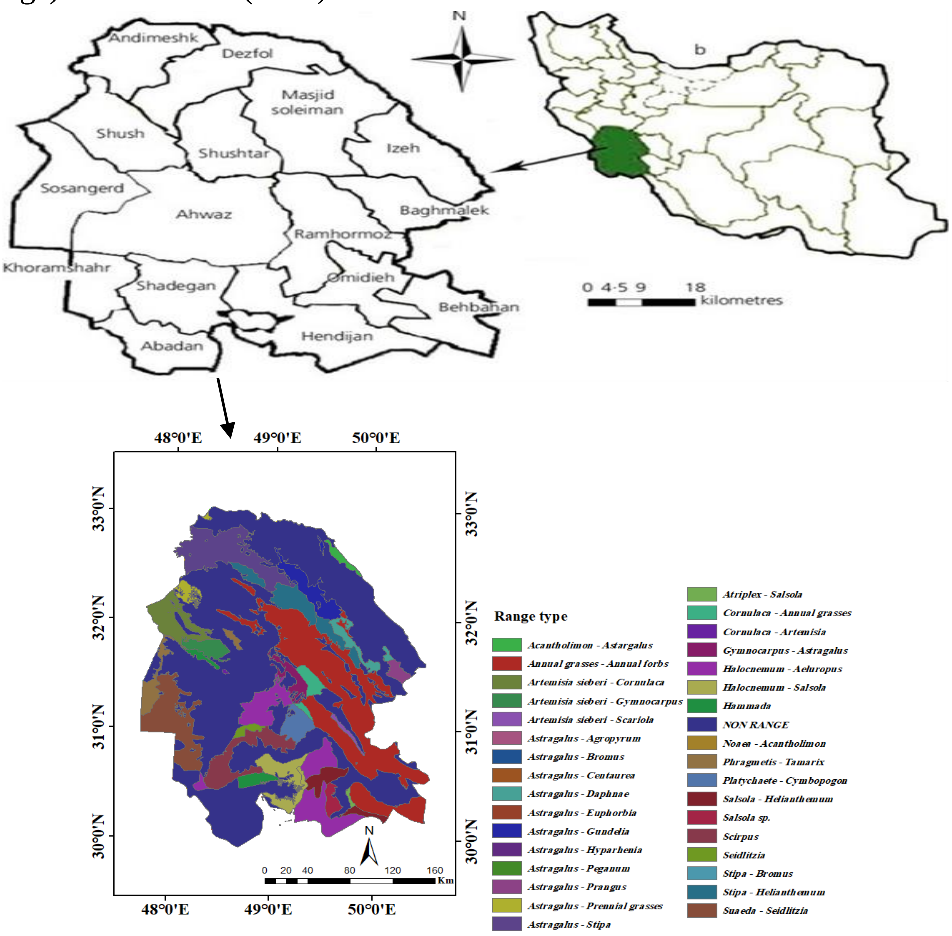


Figure (1). Location of the study area in Iran and major vegetation types of Khuzestan province (Hoveyzeh et al., 2015)

2. Materials and methods

2.1. Study area

Khuzestan province is located at the longitude 47° 41′ to 50° 39′ and latitude 29° 58 ′ to 33° 04′with an area of about 64236 m^2. Different climatic regions are observed in Khuzestan province in southwestern Iran (Figure 1). The air dryness increases from the north to the south in the area as the altitude reduces. Izeh and Abadan meteorological stations have recorded the highest and lowest annual rainfall while the region's average annual rainfall is 285 mm. The humid climate and hot and dry climate are observed in the northern and southern parts of the area. The average annual temperature in the province is 27.6°C. Forests and rangelands cover about 500 and 2.5 million hectares of the area, respectively, while 10% of rangelands is good, 30% is poor and the rest have been destroyed.

2.2. Meteorological and vegetation cover field data

The meteorological data related to the rain gauges, climatology, and synoptic stations were used for the study area and its surrounding area (Table 1). The monthly rain data were used in the study. Because of the good accuracy of the kriging method, this method was used to prepare climate maps (Almorox et al., 2005; Attorre et al., 2007).

After separating similar areas in terms of soil and vegetation, the amount of plant production was investigated. The 4-pixel method was used for measuring the amount of production of all rangeland plants in plant types with different conditions. Thirty-five GPS points were determined in each plant type. The percent of vegetation cover and leaf area index (LAI) were determined in a 500*500m^2 area with 8 plots of 10*10m^2. Then, 2*1 plots were considered for the cut and weight of the amount of all plant species production (Yeganeh et al., 2014). By considering the MODIS satellite resolution of 250*250m^2, the sampling level was determined according to Eq. 1 (McCoy, 2005).

$$A = P \times (1 + 2L) \tag{1}$$

Where A is the sampling level, P is the satellite pixel resolution in meters, and L is the acceptable error.

The 4-factor method was used for evaluating the condition of Khuzestan rangelands (Khaleghi & Aeinebeygi, 2016). The sum of the scores of four factors in the 4-factor method including soil, vegetation cover percentage, plant composition, and vigor and freshness indicates the condition of the rangeland where a score above 45 degrees is considered excellent, 38-45 good, 31-37 average, 21-30 poor, and less than 20 very poor rangeland conditions (Friedel, 1991).

Vegetation cover parameters such as cover percentage and LAI were determined based on a vector map with a radius of 250m prepared in each of the determined points. Subsequently, the ArcGIS software was used to average the value of NDVI in each of the points in the determined range. Then, the degree of correlation between plant parameters (vegetation cover percentage, plant production, LAI) and NDVI was investigated. In the calculations, the relationship between field value data and NDVI was investigated using a regression model and the coefficient of R^2 was calculated (For more information, refer to the studies by Hadian et al., 2019; Yaghmai et al., 2021). Field value data of vegetation parameters were considered as the dependent variable (Y) and NDVI value in each sampling area (250,000 m^2) was considered as the independent variable (X).

Table (1): The meteorological stations used in the study along with their geographical locations

No	Station	Year of establishment of the station (with statistics)	Longitude	Latitude
1	Aligudarz	1986	33°24′	49°42′
2	Khorramabad	1970	33°36′	48°17′
3	Pol-e Dokhtar	1999	33°09′	47°43′
4	Shahr-e Kord	1968	32°17′	50°51′
5	Lordegan	1995	۳۱°31′	۴۹ ۵۰′
6	Yasuj	1987	30°41′	51°33′
7	Dogonbadan	1994	30°20′	50°49′
8	Abadan	1965	30°22′	48°15′
9	Aghajari	1992	30°46′	49°40′
10	Ahvaz	1966	31°20′	48 °40′
11	Bandar-e Mahshahr	1988	30°33′	49 °09′
12	Behbahan	1996	30°36′	50 °14′
13	Bostan	1991	31°43′	48 °00′
14	Dezful	1964	32°24′	48 °23′
15	Hendijan	2000	30°17′	49°44′
16	Izeh	1996	31°51′	49°52′
17	Masjed Soleyman	1991	31°56′	49 °17′
18	Omidiyeh (paygah)	1999	30°46′	49°39′
19	Ramhormoz	1987	31°16′	49°36′
20	Safiabad	1987	32°16′	48 °25′
21	Shushtar	1994	32°03′	48 °50′

2.3. Satellite data

In the present study, the data of NASA's Earth Observing System (EOS)/ Land Processes Distributed Active Archive Center (LP DAAC) were used, which could be downloaded from https://earthexplorer.usgs.gov. The monthly basis by averaging 16-day images (MOD13Q1) was considered for calculating NDVI (2000-2021) and used as a monthly image, and finally, the production values were calculated for 12 months of the year (Li et al. 2015). All pre-processing and calibrations of the images were performed with the help of the MODIS Conservation Toolkit (MCTK) [48]. The monthly basis by averaging 16-day images (MOD13Q1) was considered for calculating the NDVI index (Equation 2). Data collection regarding field sampling was done monthly and finally, the total was calculated on an annual basis.

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}} \quad (2)$$

In Equation2, ρ_{NIR} is the amount of reflection in the near-infrared band with a wavelength of 867-841 nm in band 2 of MODIS and ρ_{red} is as a reflection value in the red band with a wavelength of 670-620 nm in band 1 of MODIS (Carlson & Ripley, 1997).

3. Results

3.1. The plant production and leaf area index values in plant types

Investigating the amount of plant production in the studied area showed that the amount of plant production in the area is between 120 kg/ha (Annual grasses - Annual forbs) and 474 (*Quercus brantii* - *Acer monspessulanum*) (Tables 2, 3, and 4). The amount of LAI in this research was between 0.13 to 0.002, and the plant types *Quercus brantii* and *Scirpus* spp. showed the highest and lowest values, respectively. In humid climates, compared to dry ones, the plant production and, as a result, the leaf area index is higher. While in the dry region, due to the high rate of evaporation and transpiration, the amount of leaf area index decreases. Considering that the level of resistance of plants to drought is different, plants show different strategies against drought, and on the other hand, due to the increase of roots in plants such as *Quercus brantii* with the vegetative form of a tree, the amount of moisture absorption from the soil is higher and the amount of area index is more than shrub plants such as *Scirpus* spp. Therefore, tree species such as *Quercus brantii* are not seen in arid and semi-arid climates. Production and LAI values were different in different climates. In this research, the highest amount of plant production was observed in the semi-arid climate and the lowest amount was observed in the ultra-arid climate. The amount of LAI was also higher in semi-arid climates than in arid and ultra-arid climates, and the lowest value was calculated in ultra-arid climates.

In the semi-arid climate, the highest and lowest amount of plant production was observed in *Quercus brantii - Acer monspessulanum* (474 kg/ha) and Annual grasses - Annual forbs (180 kg/ha), respectively and the LAI values were between 0.13 (*Quercus brantii*) and 0.06 (Annual grasses - Annual forbs) (Table 2). In a dry climate compared to a semi-arid climate, plant production values and leaf surface index decreased, so that in terms of plant production values, the values ranged from 300 kg/ha (*Popolus* spp. – *Tamarix* spp.) to 120 kg/ha (Annual grasses - Annual forbs) and the leaf area index value was 0.08 (Annual grasses - Annual forbs) to 0.012 (*Halocnemum* spp. – *Salsola* spp.) (Table 3). In the ultra-arid climate, the production values were between 290 kg/ha (*Hammada* spp.) and 110 kg/ha (*Suaeda* spp.– *Seidlitzia* spp.), and in terms of LAI, the values were calculated between 0.02 (*Hammada* spp.) to 0.002 (*Scirpus* spp.) (Table 4).

Table (2): Rangeland production (g m^{-2}), LAI (m^{-2} m^{-2}), correlation (R^2) between production and LAI, and production and NDVI in the semi-arid climate

	Vegetation Type	Range Condition	Plant Production (g m^{-2})	LAI (m^{-2} m^{-2})	R^2 between production and LAI	R^2 between production and NDVI
1	*Amygdalus scoparia - Ficus spp.*	forest	450	0.12	55	43
2	*Amygdalus spp. - Quercus brantii*	forest	450	0.11	54	42
3	*Amygdalus spp.*	forest	470	0.13	67	55
4	*Quercus brantii*	forest	450	0.13	63	52
5	*Quercus brantii - Acer monspessulanum*	forest	474	0.12	57	45
6	*Quercus brantii - Amygdalus scoparia*	forest	430	0.11	53	40
7	*Quercus brantii - Pistacia atlantica*	forest	440	0.11	52	42
8	*Ziziphus spina christi*	forest	400	0.9	46	34
9	*Annual grasses - Annual forbs*	grass (fair)	180	0.10	51	39
10	*Astragalus spp.- Bromus spp.*	bush-grass (poor)	280	0.07	34	22

	Vegetation Type	Range Condition	Plant Production (g m^{-2})	LAI (m^{-2} m^{-2})	R^2 between production and LAI	R^2 between production and NDVI
11	*Astragalus spp.- Centaurea spp.*	Bush (poor)	360	0.08	43	31
12	*Astragalus spp.- Daphnae spp.*	Bush-shrub (fair)	440	0.11	53	41
13	*Astragalus spp.- Euphorbia spp.*	Bush (fair)	410	0.09	49	37
14	*Astragalus spp. – Gundelia spp.*	Bush (fair)	430	0.12	52	40
15	*Astragalus spp. – Peganum spp.*	Bush (fair)	380	0.11	46	34
16	*Astragalus spp. – Stipa spp.*	Bush-grass (fair)	370	0.10	45	33
17	*Cornulaca spp.- Annual grasses*	Bush (poor)	260	0.06	32	20
18	*Gymnocarpus spp.- Astragalus spp.*	Bush (poor)	320	0.12	38.08	43
19	*Stipa spp. – Helianthemum spp.*	grass-bush (fair)	290	0.12	37	42

Table (3): Rangeland production (g m-2), LAI (m-2 m-2), correlation (R2) between production and LAI, and production and NDVI in the arid climate

	Vegetation Type	Range Condition	Plant Production (g m-2)	LAI ($m^{-2}m^{-2}$)	R^2 between production and LAI	R^2 between production and NDVI
1	*Popolus spp. – Tamarix spp.*	forest	300	0.06	36	27
2	*Annual grasses - Annual forbs*	Grass (poor)	120	0.05	31	22
3	*Artemisia sieberi – Cornulaca spp.*	Bush (poor)	220	0.06	27	18
4	*Artemisia sieberi – Gymnocarpus spp.*	Bush (poor)	260	0.04	32	23
5	*Artemisia sieberi – Scariola spp.*	Bush (poor)	230	0.04	28	19
6	*Astragalus spp.- Euphorbia spp.*	Bush (fair)	250	0.05	30	21
7	*Astragalus spp.- Prennial grasses*	Bush-grass (fair)	230	0.05	28	19
8	*Astragalus spp.- Stipa spp.*	Bush-grass (poor)	200	0.05	24	15
9	*Atriplex spp.- Salsola spp.*	Bush (poor)	280	0.03	34	25
10	*Cornulaca spp.- Annual grasses*	Bush (poor)	260	0.02	32	23
11	*Cornulaca spp.- Artemisia spp.*	Bush (poor)	240	0.02	29	20

	Vegetation Type	Range Condition	Plant Production (g m-2)	LAI ($m^{-2}m^{-2}$)	R^2 between production and LAI	R^2 between production and NDVI
12	*Gymnocarpus spp. – Astragalus spp.*	Bush (poor)	220	0.015	27	18
13	*Halocnemum spp. – Aeluropus spp.*	Shrub-grass (poor)	270	0.03	33	24
14	*Halocnemum spp.- Salsola spp.*	Shrub-bush (very poor)	200	0.012	24	15
15	*Hammada spp.*	Shrub (poor)	290	0.03	35	26
16	*Phragmetis spp.- Tamarix spp.*	Shrub-grass (poor)	160	0.03	30	21
17	*Platychaete spp.- Cymbopogon spp.*	Bush (poor)	240	0.03	29	20
18	*Salsola spp.- Helianthemum spp.*	Bush (poor)	190	0.01	23	14
19	*Salsola sp.*	Bush (poor)	200	0.01	24	15
20	*Scirpus spp.*	Bush (poor)	180	0.007	22	13
21	*Seidlitzia spp.*	Bush (poor)	200	0.04	38	29
22	*Stipa spp.- Bromus spp.*	grass (poor)	150	0.04	35	26
23	*Stipa spp.- Helianthemum spp.*	Bush-grass (poor)	190	0.01	23	14
24	*Suaeda spp.- Seidlitzia spp.*	Bush (poor)	270	0.04	33	24

Table (4): Rangeland production (g m-2), LAI (m-2 m-2), correlation (R2) between production and LAI, and production and NDVI in ultra-arid climate

	Vegetation Type	Range Condition	Plant Production (g m-2)	LAI (m-2 m-2)	R^2 between production and LAI	R^2 between production and NDVI
1	*Halocnemum spp. - Aeluropus spp.*	Shrub-grass (poor)	230	0.01	15	12
2	*Halocnemum spp.- Salsola spp.*	Shrub-bush (poor)	300	0.02	29	25
3	*Hammada spp.*	Shrub (poor)	320	0.02	32	27
4	*Phragmetis spp.- Tamarix spp.*	grass- Shrub (poor)	280	0.02	34	29
5	*Scirpus spp.*	Bush (poor)	200	0.015	30	25
6	*Seidlitzia spp.*	Bush (poor)	210	0.01	28	23
7	*Suaeda spp.- Seidlitzia spp.*	Bush (poor)	110	0.02	25	21

3.2. Correlation between NDVI index, plant production, and leaf area index

Examination of the relationship between terrestrial data, and the NDVI index showed a higher value in the semi-arid regions than in the arid regions. So the highest correlation was observed in *Amygdalus* spp. (55%) with shrub vegetative form and the lowest correlation was observed in *Halocnemum* spp.- *Aeluropus* spp. (12%). The correlation between the NDVI index and plant production was different in various climates. The correlation between leaf area index and plant production was also different among plant types and the lowest and highest values were observed in *Amygdalus* spp. (67%) and *Halocnemum* spp.- *Aeluropus* spp. (15%), respectively while the values of this relationship were higher in semi-arid than arid and ultra-arid climates.

In the semi-arid climates, the correlation between plant production and NDVI index was different. *Amygdalus* spp. (55%) had the highest correlation and *Cornulaca* spp. - Annual grasses (20%) showed the lowest correlation with plant production. The correlation between leaf area Index and pant production was different, while *Amygdalus* spp. (67%) and *Cornulaca* spp.- Annual grasses (32%) showed the lowest and highest correlations, respectively.

In arid climates *Popolus* spp.- *Tamarix* spp. (32%) had the highest correlation between the NDVI index and plant production, but *Scirpus* spp. plant type (13%) with bush vegetative form had the lowest correlation. The correlation between leaf area index and plant production was also different among plant types in this region, which was determined from 36% (*Popolus* spp.- *Tamarix* spp.) to 22% (*Scirpus* spp.).

In the ultra-arid climates, the lowest correlation between the NDVI index and plant production was observed compared to semi-arid and arid regions. R^2 values were between 29% (*Phragmetis* spp. – *Tamarix* spp.) to 12% (*Halocnemum* spp. – *Aeluropus* spp.) and the correlation between NDVI and LAI was the lowest in *Halocnemum* spp.– *Aeluropus* spp. (15%) the highest in *Phragmetis* spp.- *Tamarix* spp. (34%), respectively.

4. Discussion and Conclusion

The results of this research showed that in the study area, the amount of annual production in different plants types is different according to the type of species and its rangeland condition, and its amount is between 120 kg/ha and 474 kg/ha, which is due to the temperature difference in the altitude points, the type of plant structure, the condition of the soil and the history of exploitation (Abatzoglou et al., 2017). Andalibi et al. (2021) presented that large change patterns in land cover and land use, various meteorological conditions, and soil moisture in Ardabil Province result in its high spatial and temporal heterogeneity.

In suitable conditions, plants spend more energy on vegetative growth, therefore, the exploitation of plants in poor and very poor rangelands not only destroys the soil structure, but also reduces the amount of vegetative growth and leaf area index. Hence, these areas have lower photosynthesis and efficiency and lush leaves, which reduces the amount of production (Abdi et al., 2009). Reports have shown that in areas where the leaf area index is higher, the structure of the vegetation canopy will have less effect on the spectrum of plants, while the low leaf area index makes the physical structure and chemical composition of the stem and other components more effective on the reflection of photosynthesis (Almorox et al., 2005). Siuki et al. (2017) presented that different environmental conditions effects the maximum photosynthetic efficiency of the trees.

In average rangelands compared to very poor ones, due to the higher vegetation cover, the amount of soil protection increases, which plays an important role in reducing soil erosion and preserving minerals (Aronson et al., 1993). So that under the same rangeland conditions, the amount of LAI was measured in rangelands with semi-arid compared to arid and ultra-arid climates. In poor and very poor rangelands, the ratio of aerial to terrestrial organs decreases due to the lack of soil moisture (Attorre et al., 2007). In different plant types, biophysical characteristics and plant growth conditions, such as lack of moisture in drought conditions and physical and chemical characteristics of the soil, cause the amount of green leaf surface in the plant stem to fluctuate more on a seasonal scale (Bucci et al., 2009). Due to the low LAI in the degraded areas, the green leaf area has fewer changes compared to the better condition. According to the studies, the presence of environmental stress affecting the ecological needs of the plant causes the rate of vegetative growth of plants to decrease (Campanella and Bertiller, 2008).

In semi-arid rangelands compared to arid and ultra-arid rangelands, due to favorable climatic conditions and soil moisture, the correlation between LAI and productivity increases (Jenkins et al. 2007). So that the highest and lowest correlation between LAI and plant production were observed in *Amygdalus* spp. (67%) and *Halocnemum* spp.- *Aeluropus* spp. (15%), respectively. In the north of Minas Gerais, Brazil, an agreement between vegetation indices and the monthly precipitation pattern was confirmed for deciduous, and semi-deciduous forests (Silveira et al., 2008).

Shrubs have a longer phenology period than grasses due to their greater ability to use soil moisture (Reynolds, 1999). On an annual scale, they show a lower correlation with changes in drought in the growing season (Bucci et al., 2009). Therefore, the vegetative form of the shrub was more efficient than that of the bush, but the efficiency of the grasses was much lower than that of the shrubs (Tables 2, 3, and 4). The results of the study of Yaghmaei et al., 2021 that investigated net primary production in climate regions of central Zagros, Iran, showed that the highest and lowest NPP values were observed in the *Daphne mucronata-Prangos ferulacea* with shrub vegetation type (48.38 g C m^{-2} yr^{-1}) and annual grasses-annual forbs (3.42 g C m^{-2} yr^{-1}) vegetation type within the humid and cold and the semi-humid and cold climate zones, respectively. These results are similar to the present research.

In areas with average rangeland status, the correlation of vegetation canopy with NDVI is higher than in poor and very poor rangelands, so the highest correlation was observed in *Amygdalus* spp. (55%) and the lowest in *Halocnemum* spp.-*Aeluropus* spp. (0.12%). Cohen et al. (2003) examined the relationships between leaf area index and plant indices calculated with Landsat satellite data and concluded that each plant species has a very high correlation with plant indices. Different plant types, depending on their characteristics, show a better correlation to a certain plant index. Freitas et al. (2005) found that in deciduous forests, there is a very high correlation between the NDVI index and tree characteristics such as trunk diameter and canopy.

The correlation difference between vegetation cover and plant production with NDVI is lower in rangelands with the moderate conditions than in poor and very poor ones due to the reduction of green cover of plants in degraded areas (Tables 2, 3, and 4). Since the amount of reflection from living cover depends on the amount of water, cell structure, amount of chlorophyll, and plant structure (Sims and Gamon, 2002) and also the ratio of living vegetation, non-living vegetation, and physical components (rock, gravel, and soil) are considered as the influencing factors in spectral reflectance (Penuelas et al., 1993), the reduction of the vegetation canopy, and the vitality of plants in degraded areas also increases the effect of soil reflection on the spectrum of plants.

In addition, in these areas, the reduction of photosynthesis causes a decrease in the reflection of plants in the near-infrared spectrum, so with the weakening of the received spectrum, the correlation between the NDVI and plant parameters (vegetation cover percentage, annual production, LAI) in rangelands with the status of poor and very poor is reduced compared to the average rangelands (Peterson et al. 2002). This has been confirmed by other similar studies (Gerber, 2000). At the same time, the destruction of vegetation causes the loss of the heterogeneity of the region and the reduction of the correlation between ground data and the NDVI (Weiss et al. 2004). Morphological differences, such as the type of plant canopy, leaf shape, as well as diversity in biological activities, cause differences in the reflection of plants in different bands (Moreno-de las Heras et al., 2015), which makes it possible to identify plant types in different regions (DeFries and Townshend, 1994; Ustin et al. 199۹). Qiao et al. (2019) indicated a weak relationship ($p > 0.05$) between LAI and vegetation indices during the flowering period. The inadequate sensitivity of NDVI in the estimating of LAI was also reported by Towers et al. (2019).

In general, the results of this research indicated that plants show different strategies in different climates. In arid and ultra-arid climates, plants have deep roots to adapt to the dryness of the soil, but in general, the production of plants in semi-arid areas is more than in ultra-arid areas. It can be said that the leaf-to-stem ratio is lower in these areas. With the reduction of leaf area, the correlation between LAI and plant production, as well as plant production and NDVI, decreases. In addition to the amount of greenness, the distribution pattern of plants and the percentage of vegetation cover can be considered as one of the reasons for reducing the correlation between plant production and NDVI. Therefore, by knowing and studying plants in the form of different types in certain climatic classes, it is possible to measure the amount of plant production. In addition, more accurate results can be obtained in vegetation cover studies by considering more classifications in ultra-arid areas. Also, it should be noted that because the general purpose of this study was to investigate climate changes on rangeland and forest vegetation, and in agricultural areas, human interventions such as plowing and irrigation cause changes in climatic effects on plants, agricultural lands were not considered in this study and need to be investigated in another study.

Acknowledgements

This study was funded by Iran National Science Foundation (INSF). We are grateful to the INSF for financial support of the research with grant No. 99011835.

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