Estimation of Plant Production for sustainable use of Arid and Semi-arid Rangeland Ecosystems Using Satellite Data

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Abstract: Regarding the role of rangelands in natural ecosystems and protection of water and soil, precise and principled management of these arenas seems necessary. Sustainable rangeland management practices are considered to be a solution to manage forage and rangeland degradation. In this study, plant production of arid and semi-arid rangeland in the northern province of Fars during period of 2006 and 2008 were estimated. Four sites were selected and production of plant species of 60 plots was measured. Different digital data were produced and correlation between these data and plant production calculated. The obtained data of the field measurements showed that the rangeland of these regions have little production on the whole. The estimation results of plant production in growth areas under study through LISS-3 digital data shows that there is a significant relationship between total production and digital data. In addition, our results indicate that there is no similarity between produced regression patterns in different studied sites and years.

***Keywords*:**LISS-3 sensor, plant production,regression,vegetation indices.

Introduction

Achieving sustainable increases in rangeland production in arid and semi-arid areas is both a regional and a worldwide concern. Rapid population growth in most of developing countries have surpassed land-carrying capacities causing destruction of natural ecosystems and weakens the long-term stability of these production systems. Monitoring the sustained productivity of rangelands helps managers to optimize the rangeland's potential and maintaining a balance between human and animal populations from a grazing and habitat perspective [1]. The major ecological and economic values of rangelands lie in their capacity for plant production and their efficiency in soil conservation. In the other words, the two very important factors representing the ecological and economic values of rangelands are canopy cover and plant production [2]. Therefore, evaluation of rangelands is an important principle in recognizing the basic factors for their management. Satellite images can serve as a tool in estimating quantitative parameters of extensive rangeland areas[3,4]. This research intended to evaluate the capability of LISS-3 sensor images in estimating plant production from rangeland species in the study areathat aim at enhancing the sustainable management of rangelands. The results of this study will be useful for development and extension practitioners in guiding and increasing the efficacy of future interventions for sustainable rangeland management in the dry and semi-dry areas, like our study area.

Materials and Methods

Case study

This research was conducted at four sites (sites 1 and 2 in the arid regions and sites 3 and 4 in the semi-arid regions) related to the National Plan to Evaluate Pastures in Different Climatic Zones in northern Fars Province. The average rainfall in the arid and semi-arid regions is 164 and 220 millimeters, respectively, and the dominant plant species is *Artemisia sieberi* in the arid regions and *Astragalus reuterianus* and *Astragalus susianus* in the semi-arid regions.

Methods

The canopy covers in 60 plots in each study site wasestimated, and a double sampling procedure suggested by Arzani and King [4] was employed to measure plant production. For this purpose, the canopy of plant species (in percentages) in all of the plots were measured as indirect method and production in 15 plots was measured using the cutting and weighing method. Both data on plant production and canopy covers was then used for calculating

regression equation. Finally, production of plants in other plots (i.e. 45 plots in each site) was estimated using this regression equation. The plant data were sampled in 2006 and 2008.
The images used in this research were obtained from the LISS-3 sensor of the IRS-ID satellite for 13 May 2006 and 11 June 2008. LISS-3 is a four-band multispectral sensor with narrow bands: 0.52-0.59 µm (green), 0.62-0.68 µm (red), 0.77-0.86 µm (near infrared), 1.55-1.70 µm (middle infrared). A series of pre-processing procedures (geometric and radiometric corrections) were performed on the images. Eighteen vegetation indices were then derived (Table 1) similar to what was done in research of Keshtkar et al. [5]. Furthermore, principal component analysis (PCA) was extracted from satellite images, and the first PCA-band was employed in the analysis. Then, to study the efficiency of satellite images in estimating quantitative vegetation parameter (i.e. plant production), the numerical values of vegetation indices, PCA1, and four bands of LISS-3 sensor were compared with plant production data in 2006 and 2008. Finally, among the spectral information, the data that had the strongest correlation with the vegetation parameters was selected to obtain the regression equation.

Table 1: Vegetation indices used in the study [5]

Code	Vegetation Index	Formula
DVI	Deference Vegetation Index	NIR-RED
GNDVI	Green Normalized Difference Vegetation Index	(NIR-GREEN)/(NIR+GREEN)
IPVI	Infrared Percentage Vegetation Index	NIR/(NIR+RED)
LAI	Leaf Area Index	NDVI/(3.26-2.9+NDVI)
LWCI	Leaf Water Content Index	(NIR-MIR)/(NIR+MIR)
MIRV	MIRV	(MIR-RED)/(MIR+RED)
MSI	Moisture Stress Index	MIR/NIR
NDVI	Normalized Difference Vegetation Index	(NIR-RED)/(NIR+RED)
NRR	NRR	(NIR-RED)/RED
NRVI	Normalized Ratio Vegetation Index	(RVI-1)/(RVI+1)
PD322	PD322	(RED-GREEN)/(RED+GREEN)
RA	RA	NIR/(RED+MIR)
RVI 1	Ratio Vegetation Index 1	NIR/RED
RVI 2	Ratio Vegetation Index 2	Sqrt (NIR/RED)
TNDVI	Transformed Normalized Difference Vegetation Index	(NDVI+1)*100
TVI	Transformed Vegetation Index	(NIR-RED)/(NIR+RED)+0.5
VI 1	Vegetation Index 1	RED*NIR/GREEN
VI 2	Vegetation Index 2	RED*NIR

Results

Results showed that there was a significant relationship between annual plant production and annual rainfall (except for site 3). Site 4 in the semi-steppe region with the annual production of 435 kg/ha in 2006 and 95 kg/ha in 2008 had the highest production among the sites (Fig. 1).

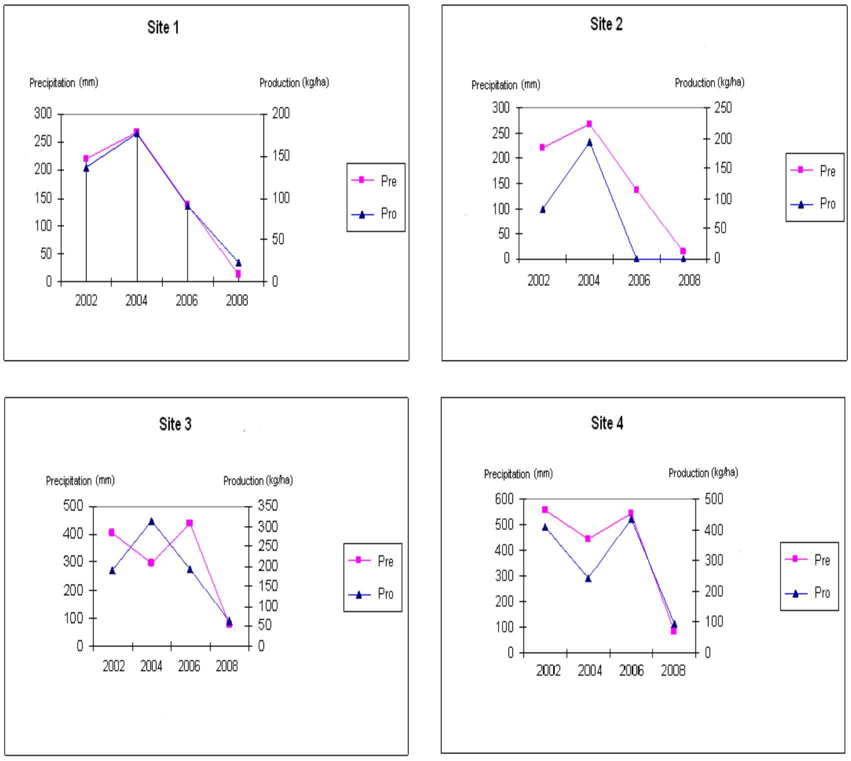

Figure 1: The relationship between annual rainfall and plant production in the studied sites. Pre= precipitation; Pro= plant production

Table 2 presents the satellite data that had a significant correlation ($p \leq 0.05$) with plant data. These results indicate that, in all, band number 4 of the LISS-3 sensor (middle infrared) had the strongest correlation with the quantity of plant produced in the four study sites. Since 2008 was a year of severe reduction in rainfall, very little forage was produced in sites 1 and 2 and, for this very reason, no correlation was found between satellite data and plant production in this year. Results of regression analysis in the studied sites are shown in Table 3.

Discussion

Results of this research indicated that changes in production of various plant species in the studied rangelands were influenced by rainfall fluctuations. Therefore, a linear relationship between rainfall and primary production for dry and semi-dry rangelands can be presented. Previous studies showed that the most important factors that influenced changes in vegetation were drought and long term variations in the amount of rainfall [4]. Although changes in rainfall is often said to be a dominant driver in arid rangelands [6], and are likely to affect plant production [7,8], the very low quantity of plant produced in 2008 in the arid regions (sites 1 and 2) cannot be attributed only to rainfall. Therefore, factors other than rainfall, including the growth forms of the plant species, aquifers, and/or management must be studied to find the reason for the severe reduction in plant production in these two sites.

Table 2: Correlation between satellite data and total plant production (significant p≤0.05)

Sites	Year	Digital data	Correlation coefficient (%)
Site 1	2006	Band 4 GNDVI CTVI	37 36 34
	2008	*	*
Site 2	2006	CTVI GNDVI Band 4	27 25 24
	2008	*	*
Site 3	2006	Band 4 GNDVI CTVI	38 27 25
	2008	Band 4 NRR GNDVI RVI1 CTVI	29 28 27 26 25
Site 4	2006	Band 4 GNDVI CTVI	38 27 25
	2008	PCA1 VI2 VI1	30 29 27

Table 3: Regressive relationships between plant production and satellite data

Sites	**Year**	**Satellite data**	**Regression**	**R**	**Std. Err.**	**P-value**
Site 1	2006	Band 4	Y= 0/02+4/46 B4	0.37	0.02	0.01
	2008	*	*	*	*	*
Site 2	2006	CTVI	Y= 0/002+./06 CTVI	0.27	0.02	0.01
	2008	*	*	*	*	*
Site 3	2006	Band 4	Y= -1.49+5.54 B4	0.48	0.06	0.01
	2008	Band 4	Y= -3/52+3/38 B4	0.28	0.006	0.01
Site 4	2006	Band 4	Y=./02+./446 B4	0.38	0.04	0.01
	2008	PCA1	Y=./03+./041 PCA1	0.30	0.04	0.01

Results of estimating the production of the plant species in the studied vegetative areas using digital data of the LISS-3 sensor showed that in the studied years there were significant relationships between total plant production and the digital data. Therefore, the subject of insufficient spatial coverage and temporal variability in ground sites for recognizing plant production in arid and semi-arid rangelands can be addressed by the use of time series LISS-3 images.

Since change of rangelands condition in arid and semi-arid lands is gradual, designing an estimation system in a given time period for continuous measurement of qualitative and quantitative parameters of vegetation is necessary.

The rangeland monitoring system also was considered by Kossler [1] in USA, and Western Australia [9] in shrubland. This monitoring system was designed to report vegetation change in pastoral lands. They reported from Western Australia that the negative impact of grazing had been less than the positive impact of rainfall over the assessment period.Integration of satellite data and the results of estimation system can be valuable in rangeland management, especially in drought conditions. Generally, continuous monitoring of rangeland condition has very high social and environmental benefits as they increase the sustainability of the rangeland ecosystems, and reduce desertification specifically in arid and semi-arid climates [11]. Moreover, these findings can be considered as a strategic guide to rangeland management, and help local authorities (policy makers, ranchers and natural resources managers) better understand a complex ecological system and develop rangeland management that can better balance rangeland productions and local needs.

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