OPEN ACCESS Freely available online

Journal of Remote Sensing & GIS

Research Article

Relationship of Vegetation Indices Derived from Sentinel 2A Image with Canopy Cover and Production

Jamal Imani*

Department of Ecology, University of Tehran, Iran

ABSTRACT

The present study was conducted to determine the best ground and spectral resolution (Sentinel 2A images) for estimating vegetation cover and production. Ground sampling was performed in three plant communities in two forms of six and three plots. Different dimensions of the nesting plot (including 1×1, 2×1, 2×2 and 3×3) were used to estimate production and cover. Samples were taken in each community within 30 pixels along three transects. Densities of dominant plants were calculated by counting the bases in 2×2 plots, of vegetation cover as estimated and production was measured by double sampling in relation to of cover. Also, the distribution of dominant species was determined by statistical tests. The results showed that in community 1, using 10 m resolution bands, NDVI, CTVI, MSAVI2, Ratio, RVI, SAVI and TVI had significant relationship with of cover and production. In community 1, 1×1 plot has no significant relationship and valid model and in other plots, three-plot sampling method has very low correlation and the resulting models are insufficiently valid while sampling method is insufficient but The six plots method has a significant correlation. In community 2, the indices of NDVI, Ratio, RVI and TSAVI1 have significant relationships. In community 3, except plots 1×1 and 2×2, other plots had good relationships in the six plots sampling method and NDVI, MSAVI2, Ratio and TVI indices had good relationships in this community. In using of Sentinel 2, with bands 60 meters, the results are somewhat different. In community 1, MSAVI2 and RVI indices, in community 2, TSAVI1 and RVI and in community 3, NDVI and Ratio have significant relationships. In using these bands (with a resolution of 60 m), both sampling methods are less correlated. In community 1, 2×1 plot with six plots method, in community 2, 3×3 plot with three plots method and in community 3, 2×2 plot with six plot method is suitable.

Keywords: Rangeland Assessment, Remote Sensing, Spectral Resolution, Ground Resolution, Vegetation Indicators, Vegetation Coverage and Production

INTRODUCTION

Recognizing and evaluating rangeland ecosystems is the first step in managing these resources. It is important to know the fastest and most cost-effective methods for analyzing and evaluating rangelands. This is something that almost all scientists in the field of metrology sciences emphasize. Using satellite data is one of the best ways to study ecosystems at a lower cost.

Features such as providing a broad and integrated view of a community, reproducibility, ease of access to information, and high accuracy of the information obtained and time-saving are features that make the use of such information relatively valuable for vegetation surveying (Campbel et al, 2011). Therefore, many researchers have used remote sensing data to study vegetation and have found this technique suitable for such studies (Mousavi et al. 2006; Hadian et al. 2013).

In order to use satellite data to identify sources, the impact of factors such as topography, soil reflection, atmospheric effects must be reduced or eliminated as far as possible. Then, using different methods, it is found out the relationship between these

***Correspondence to:** Jamal Imani, Department of Ecology, University of Tehran, Iran, Tel: 989181836010, E-mail: Imani.j.1986@gmail.com

Received: June 23, 2020; **Accepted:** August 31, 2021; **Published:** September 10, 2021

Citation: Imani J (2021) Relationship of vegetation indices derived from Sentinel 2A image with canopy cover and production. J Remote Sens GIS. 10:p313

data and the ground phenomena. This relationship can be between one of the plant characteristics such as crown cover and indices.

Different vegetation indices have been devised by scientists to study vegetation, and Anderson et al, 1993 stated that vegetation indices exhibit different responses to vegetation, suggesting that these relationships are difficult to quantify. Because these relationships are influenced by factors such as the angle of the sun's radiation, atmospheric absorption, the reflection of shadow phenomena, the stages of plant growth and change. Accordingly, the results of the researchers' research so far can be distinguished in three groups:

The first group, Anderson et al, (1993) report a clear and distinct relationship between vegetation characteristics and spectral bands poorly reported. The second group reported a significant relationship between spectral bands and vegetation characteristics, such as Pour Mohammadi et al., 2012, Yichun Xie et al. 2008, Ahmed et al. 2011, Lawley et al. 2016, Edward et al. 2008, Robert et al 2006.

The third group, such as Pickup et al., Qi et al, 1994, Eagleson et al, 2009, Hadian et al., 2013, believe that the above relationship is dependent on environmental conditions and may be related to some environmental conditions. Significant points in adjacent areas due to factors such as heterogeneity of vegetation, low of vegetation and biomass, soil effects, etc. This relationship is weak or meaningless.

The lack of facilities and sufficient capital does not allow the entire rangeland to be surveyed on land. Using satellite data also requires ground sampling. Distribution and type of sampling, number and dimensions of terrestrial samples are of particular importance. Field data collection is one of the most important issues in remote sensing tasks. Congalton et al., 2008 states that field data collection has three goals: 1: Can be used to evaluate remote sensing data, 2: Provides reliable basis for statistical testing, and 3: Provides information for the resolution characteristics of eye-catching features. Because the satellite image data is extracted from the pixels and is a reflection of the pixel surface, then the ground sample must be selected to represent the total pixel. The sample area and number of pixels should not be low because it cannot be a good representative of the whole pixel and should not be too large in size because lack of facilities and time will not allow work and due to expert fatigue, estimating parameters the measurement case also faces an error (Arzani, 2014). Therefore, further research is needed to better utilize satellite digital data for estimating plant quantitative traits based on the results obtained, the differences of opinion expressed or the knowledge gained in this area. Given the different results obtained by different researchers in applying remote sensing to identify and evaluate rangeland vegetation, the motivation for such research in semi-arid conditions of Iran with the aim of determining the appropriate model in different sampling patterns and dimensions, productions efficiency and Sentinel 2 satellite images (with resolution of 10 and 60 meters) as well as introduction of suitable vegetation indices for estimating cover and production in three vegetation communities with different vegetative forms were provided.

MATERIALS AND METHODS

The position of the studied plant communities: The study area is located 40 km southwest of Shahrekord near Choghakhor Wetland in Chaharmahal va Bakhtiari Province. In terms of climatic divisions, is semi-steppe. This region is located at latitude 94 94 94 ° 31 to 98 00 ° 32 North and longitude ″50 ′85 ° 50 to 87 50 20 ° East. The average annual rainfall at Overgan Station at a distance of about 10 km is about 450 mm (Chaharmahal & Bakhtiari Provincial Meteorological office, 2016).

Figure 1. Location of study area and vegetation communities on Google Earth

The vegetation characteristics of the three vegetation communities investigated are presented below: Physiographic Specifications: Gundellia tournefortii-Couisinia bachtiarica community in altitude range 2250 to 2560 m and slope of 8 to 54%, Daphnea mucronata-Astragalus adscendence community in altitude range 2300 to 2650 m and slope 24 to 67% and Melica persica-Agropyron trichophorum community in range 21 Up to 2400 meters and slope 22 to 43 percent.

Research steps

A) measurement and processing of ground data

Identifying Communities

First, three plant communities with different dominant species were selected.

Selection of sampling units

Within each study community, sampling areas were identified. Then within this range, 30 sampling units 30×30 m with 60 m distance along three 900 m transects were selected in horizontal direction. So that 10 sampling units were systematically deployed along each transect.

Establishment of sampling patterns within sampling units

Within each sampling unit 30×30 meters, two different sampling patterns were considered in terms of plot number and arrangement. Whereas pattern one had 6 and pattern two had 3 plots. The 6-plot pattern was arranged in two rows, and the 3-plot pattern was arranged in a row in the middle of the sampling unit (Figures 2 and 3).

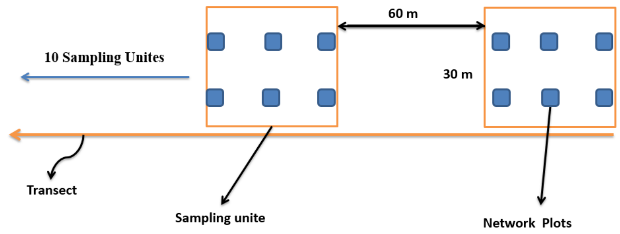

Figure 2: How to arrange nested plots inside sampling units in Method 1 with 6 plots

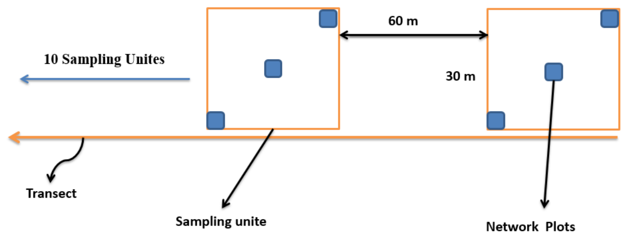

Figure 3: How to arrange nested plots inside sampling units in method 2 with 3 plots

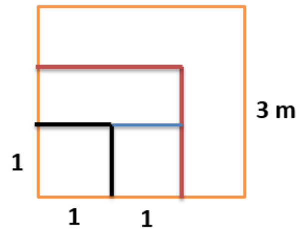

Figure 4: nested plots

Plots

Each of the plots used in the two sampling patterns and had 4 nested plots size.

Record

Record sampling points using the Global Positioning System (GPS).

Measuring cover and production

Within each plot size, the cover of the plant species was estimated and for measurement plant production use double-sampling method. The canopy cover of all plant species was measured in all plots, but plant species production was cut in Method 1, in two plots of six plots and in Method 2, in one plot of three plots. Then, using regression equation between vegetation canopy and production of cut and weighted plots, plant species production in all plots was estimated.

Measurement of dominant plant densities

In each plant community within 2×2 m plots of dominant species density was counted which was used to find out the distribution pattern. 8- Data Summary and Extraction of Plant Factor values were executed after field surveying.

B) Satellite data collection and processing

Sentinel 2A image from the sampling time

(S2A_OPER_MSI_L1C_TL_MTI), (June 16, 2015) and for atmospheric correction, the Dark subtract method, which is a fractional method, was used. This is how Subtraction was done based on Band Minimum. Geometric correction was done by using a geo-referenced image that was previously prepared as a reference. Initially two RGB images were created. The 15 points were selected as control points in two images (Base and Warp) and the RMSE was 0.95.

Spectral Ratio (Vegetation Indices of Remote Sensing)

In the present study, various indices based on the combination of spectral bands were developed and used in the analyzes (NDVI, MSAVI, SAVI, TSAVI1, PVI, WDVI, DVI). The vegetation factors (canopy cover and production) were considered as dependent variables and vegetation indices were considered as independent variables. For calculation of indices in image processing, Sentinel 2 band 4 (0.665) was considered as red and band 5 (0.845-0.888) and bands 8, A8, 7 and 6 were considered as infrared band.

Extract the values of the vegetation indices at the sampling points

After calculating the vegetation indices in TerrSet, maps of each index were transferred to ArcGis and extracted in excel table in ground GPS point (ground sampling points).

Extracted spectral values

The extracted spectral values with ground vegetation data were transferred to SPSS and the regression relation between vegetation characteristics measured in plots and their corresponding spectral values (Indicators) obtained. In regression models, canopy cover and production were considered as dependent variable and vegetation indices as independent variable.

Testing and validating regression models to select the appropriate model and index

In order to test and validate the regression models, 65% of the data were used for model building and the remaining 35% for model testing. In this model, the index numbers were inserted in the model and the difference between the corresponding vegetative factors was estimated by paired t-test. The absence of the model is the opposite, and vice versa. The RMSE index was also calculated for each model and the different models were compared. 6- Statistical methods in Ecological Methodology software were used to find out the distribution of dominant species in each community.

RESULTS

Results distribution pattern of dominant species in three study communities:

Community 1 dominant species are randomly distributed. In community 2, the distribution pattern of Daphne mucronata and Astragalus adscendence are complete uniform. In community 3, Festuca ovina and Agropyron trichophorum have a clumpy pattern, and Melica persica has uniformly clumped.

Results of regression analysis of plant factors and different indices

To extract some vegetation indices such as PVI, TSAVI1, DVI and WDVI, the regression between red and near-infrared bands must first be calculated and the origin and slope of the regression line used to derive the above indices. Whereas for the PVI and WDVI, infrared is dependent and near infrared is independent variable and for DVI and TSAVI1 on the contrary (figures 5, 6, 7 and 8).

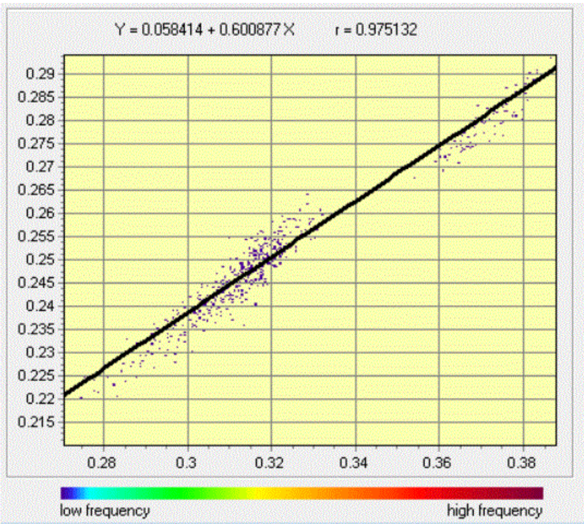

Figure 5. Sentinel 2 soil line regression with 10 m resolution - infrared is dependent and near infrared is independent variable

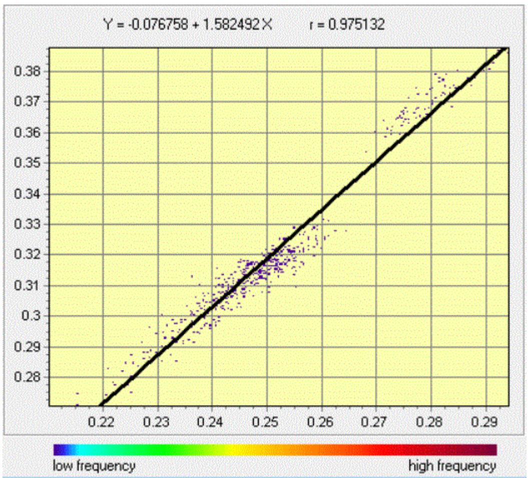

Figure 6. Sentinel 2 soil line regression with 10 m resolution – infrared is independent and near infrared is dependent bands

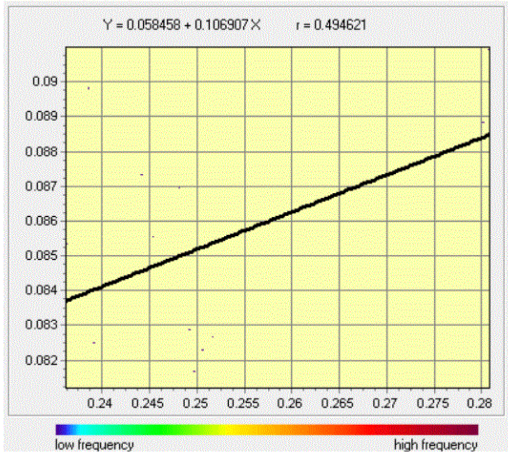

Figure 7. Sentinel 2 Soil Line Regression with 60 m Resolution – Red band is Independent and Near Infrared is Dependent

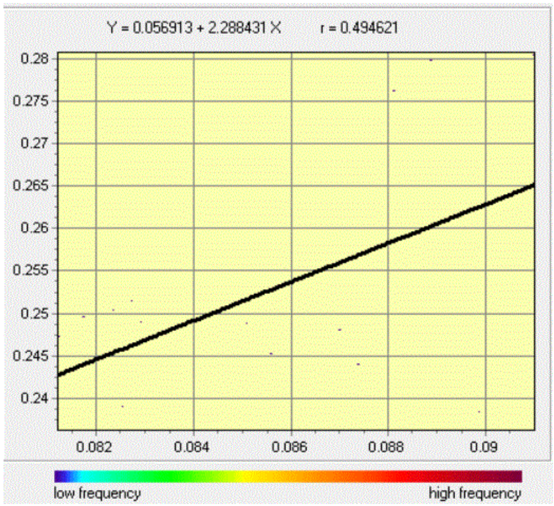

Figure 8. Sentinel 2 Soil Line Regression image with 60 m resolution – infrared is dependent variable and near infrared is independent

Vegetation indices maps

The polygon map of the vegetation indices derived from Sentinel images (10 and 60 m resolution) is shown in Figures 9 to 18. As can be seen, each indices of the images with different resolution has a different range in the electromagnetic spectrum.

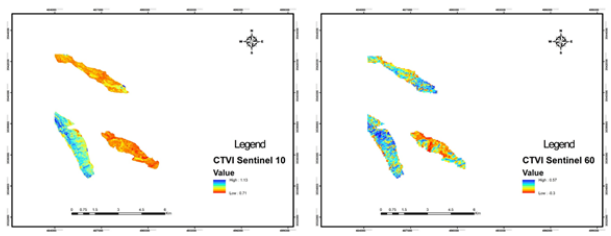

Figure 9. CTVI index map derived from image and sentinel (10 and 60 m resolution)

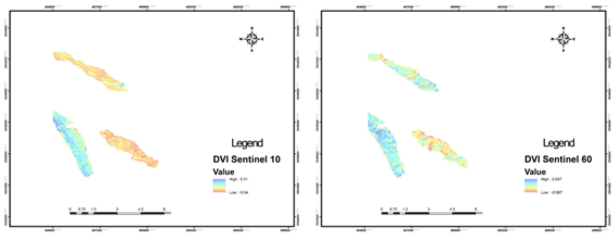

Figure 10. DVI index map from Sentinel image (10 and 60 m resolution)

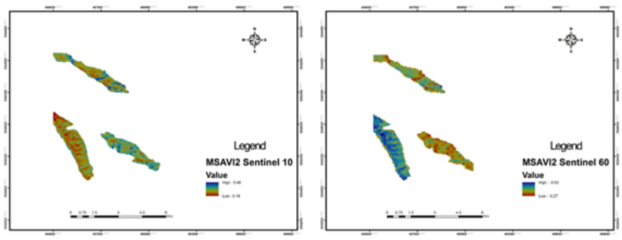

Figure 11. MSAVI2 Index Map from Image and Sentinel (10 and 60 m resolution)

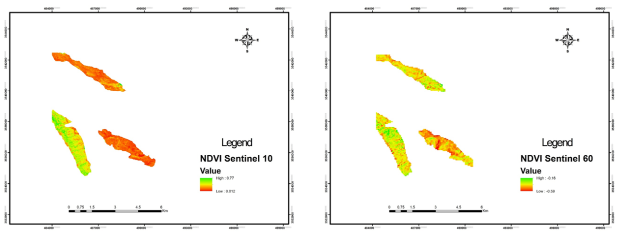

Figure 12. NDVI index map of image and sentinel (10 and 60 m resolution) in polygon

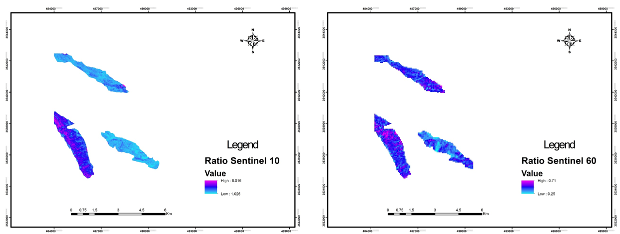

Figure 13. Ratio map image and sentinel (10 and 60 m resolution)

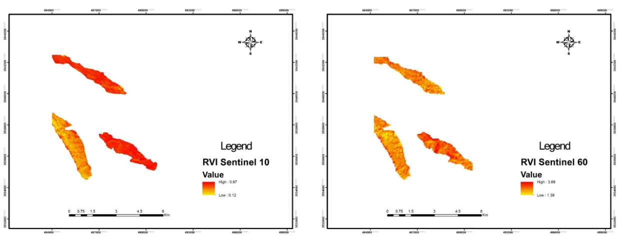

Figure 14. Map of RVI index from image and sentinel (10 and 60 m resolution)

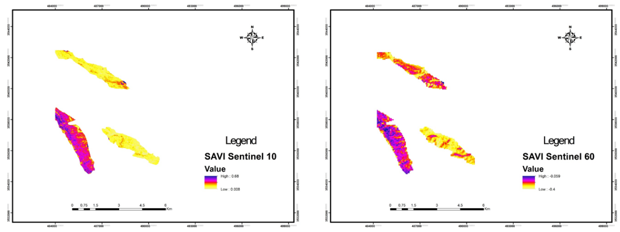

Figure 15. SAVI Indicator Map from Image and Sentinel (10 and 60 m resolution)

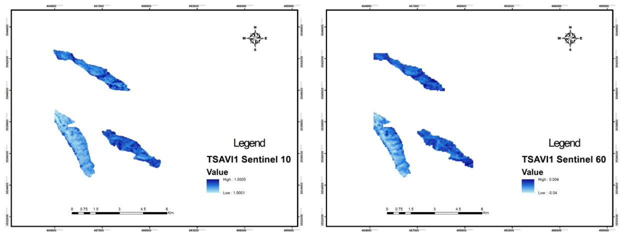

Figure 16. TSAVI1 Index Map from Image and Sentinel (10 and 60 m resolution)

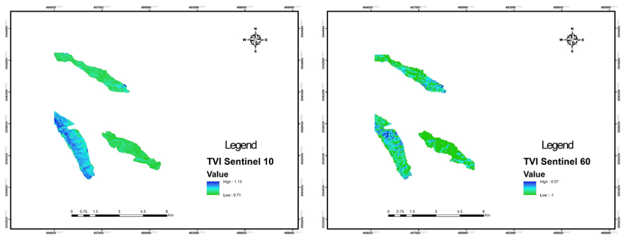

Figure 17. Map of Index TVI from Image and Sentinel (10 and 60 m resolution)

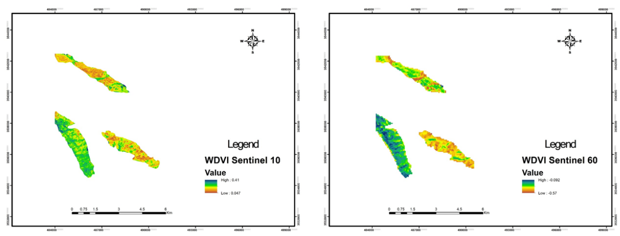

Figure 18. Map of WDVI from image and sentinel (10 and 60 m resolution)

Results for plant community 1 (image 10 m resolution)

Most relationships of NDVI, CTVI, MSAVI2, Ratio, RVI, SAVI and TVI indices in community 1 were significant with respect to vegetation and crop production. The correlation between sampling method 1 (six plots) is higher than the correlation method of sampling method 2 (3 plots). As the level of the plot increases, in most cases, their significance is increased.

RMSE and paired t-test were used to determine the validity of the models. The larger RMSE is as lower the validity of the model, and the higher the difference in the factor extracted from the land and the resulting model is increased and significant, and therefore the model will not have sufficient validity. In most indices, the models obtained in 1×1 meter plots in both sampling methods are not valid enough. Because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high.

The correlation coefficient of regression equations for most of the indices in 1×1 plots is not significant and the resulting model is insufficiently valid. Also in the 1×2 plots the relationships obtained in the sampling method 2 (three plots) are not significant and the resulting model is not sufficiently valid.

Results for plant community 2 (image 10 m resolution)

In this community, most of the relationships of NDVI, Ratio, RVI and TSAVI1 indices with respect to vegetation and crop production were significant. Similar to community1, correlation between sampling method 1 (six plots) is higher than the correlation method of sampling method 2 (3 plots). As the level of the plot increases, in most cases the correlation and significance is increased. In most of the indices, the correlation in plots 1×1, 1×2 and sometimes 2×2 (especially in sampling method 2) has less significance, whereas the correlation in plots 3×3 is significantly higher. Significant relationships of TSAVI1 index were higher than other indices. Also in this community, in most of the indices the models obtained in 1×1, 1×2 and 2×2 plots in both sampling methods are insufficiently valid. whereas, the regression equations in 3×3 plots, especially in sampling method 1, are valid.

Results for plant community 3 (image 10 m resolution)

Most relationships of NDVI, MSAVI2, Ratio and TVI were significant with respect to vegetation and crop production. As in the other two communities, the correlation coefficient in sampling method 1 (six plots) is much higher than the correlation rate in sampling method 2 (3 plots). As the level of the plot increases, in most cases the correlation is increased too. Significant relationships of TVI index were more significant than others. In this community most of the correlations in 2×2 and 3×3 plots are significant.

In most of the indices, the models obtained in 1×1 and 1×2 plots in both sampling methods are insufficiently valid. Plot 2×2 and 3×3 are also sometimes insufficiently valid in sampling method 2 (three plots). Because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high. Also, the correlation between regression equations in most of the indices in 1×1 and 2×2 plots was not significant and the resulting model was insufficiently valid. In the 2×2 plots, the relationships obtained in sampling method 2 (three plots) were not significant and the model obtained from them was not sufficiently valid.

Results for plant community 1 (image 60 m resolution)

In this community, most of the relationships between MSAVI2 and RVI indices with respect to vegetation cover and production were significant. In general, the correlation is not high. The correlation between sampling method 2 is less than sampling method 1. In this community, in most of the indices the models obtained in 1×1 plots in both methods and in 2×2 plots in Method 2 are not valid enough. Because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high. Significant correlations and regression relationships were found in most indices with low coverage. So, the models obtained from sampling method 1 in plots 1× 2 and 2×2 have sufficient validity.

Results for community 2 (image 60 m resolution)

In this community, most of the relationships of TSAVI1 and RVI were significant. The correlation between sampling method 2 is less than sampling method 1. Correlation in 3×3 plots is significant in both sampling methods and in other plots either is not significant or has low significance.

Most of the indices obtained in the 3×3 m plots in sampling method 1 are sufficiently valid and the rest of the models are unusable because the difference between the land cover factor and the meaningful model is significant. And their RMSE is remarkably high. Significant correlation coefficients of regression equations were found to be low in most indices. And only the model on the 3×3 plots is valid.

Results for community 3 (image 60 m resolution)

In this community, most of the relationships of NDVI and DVI were significant. Correlations in 1×1 and 1×2 plots in two sampling methods were not significant and in most of the indices, the models obtained in 1×1 and 1×2 plots in both sampling methods are not valid enough because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high. The models in Plot 2×2 and 3×3 have considerable validity.

DISCUSSION

Plant distribution pattern

In this study Plant distribution pattern was performed using Poisson statistical tests, negative and positive binomial. Plants are random, clustered, and uniform if the data follow the Poisson distribution, negative binomial, and positive binomial, respectively. The dominant plants of community 1 have a uniform pattern. Whereas the dominant plants of community 2 which are bushes have a uniform distribution pattern and the dominant plants of community 3 have a clumped distribution pattern.

In general, the more uniform the distribution pattern of plants, the more sampling is needed so that the intensity of sampling can be representative of the whole sampling unit or plant community. Therefore, it is likely that in order to achieve the desired goals in estimating vegetation factors such as canopy cover and production, community 3 requires more samples per identical sampling unit than the other two communities.

Discussion of regression analysis and testing of vegetation indices (10 m resolution)

Community 1

As stated in the results section, most of the relationships of NDVI, CTVI, MSAVI2, Ratio, RVI, SAVI and TVI in community 1 were significant in terms of vegetation cover and production. However, all relationships between these indices were not significant and the correlation was higher in sampling method 1 (6 plots) and much less in sampling method 2 (3 plots).

The reason for the increase in the correlations of indices obtained from bands 10×10 in Sentinel images in sampling method 1 and its decrease in sampling method 2 is probably due to the type of sampling and the distribution of plots for field harvesting. Six-plot dispersion, more surface area relation to 10×10 meter pixels, and sampling accuracy increases, whereas in three-plot sampling, only one plot is within pixels and sample accuracy is low. The vector goes down and the resulting correlation will be very low.

The correlations of these indices in the 1×1 plot are very low, which means that the 1×1 plot is not suitable for this community. Significant relationships between RVI index and SAVI were found to be significant, and Zhang-Yu et al.'s (2007) results also supported this idea. Also the results of Smith et al.'s (1989) study showed high correlation of RVI index with coverage. Correlation of other indices (DVI, NRVI, PVI, TSAVI1 and WDVI) was not significant and their results were not presented.

In most of the indices, the models obtained in 1×1-meter plots in both sampling methods are not valid enough. Because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high.

In this community with the dominant herbage plants and random distribution, the 1×2 plot has good results and is easier to use than the 2×2 and 3×3 plot and it is recommended to use it under similar conditions. The results of Zare chahuki et al.'s (2013) and Baranian et al.'s (2013) research are somewhat similar and confirm that in communities with small-sized plants, large-scale plots would not be appropriate with this part of the results.

Community 2

In this community, most relationships of NDVI, Ratio, TSAVI1 and RVI with respect to vegetation and crop production were significant. But the level of meaningfulness in each plot varies with increasing plot level, in most cases the correlation coefficient increases and their significance increases further.

As in community 2, in most cases, plot 3×3 and 2×2 have significant correlations, which means that in this community with large dominant plants, the large plot was suitable. In this community, the correlation between sampling method 2 is less than sampling method 1. Correlation in 3×3 plots is significant in both sampling methods and in other plots is not significant or has a low significance. In this community in most of the indices, the models obtained in 3×3 m plots in sampling method 1 are sufficiently valid. In sampling method 2, most models have less validity or invalidity while in sampling method 1 they are more valid. The results of crop production survey are trend of increasing and decreasing the correlation coefficient is the same as the of vegetation cover.

Community 3

In this community, most of the relationships of NDVI, MSAVI2, Ratio and TVI indices were significant. In the other two communities, the correlation between sampling method 1 (six plots) is much higher than the correlation method of sampling method 2 (3 plots). In this community, in most of the indices, plot 1×1 and 1×2 were not highly correlated, whereas plot 2×2 was well correlated. Significant relationships of TVI index were more significant than others. In most of the indices, the models obtained in 1×1 and 1×2 plots in both sampling methods are insufficiently valid. Plot 2×2 and 3×3 are also sometimes insufficiently valid in sampling method 2 (three plots). Because the difference between the ground cover factor and the model result is significant and their RMSE is also significantly high. So plot 2×2 with 6 sampling unit is suggested in similar condition.

Discussion of regression analysis and testing of vegetation indices (60 m resolution)

Community 1

In this community, most of the relationships between MSAVI2 and RVI indices with respect to vegetation cover and production were significant. In other words, these indices from the 60-m image were able to correlate with plant cover and crop production. In general, the correlations are not high. The correlation between sampling method 2 is less than sampling method 1. Significance and correlation between these two indices is low compared to the 10 m sentinel bands image, because the pixel size of the bands used is 60×60 m and sampling within these pixels and on the ground, especially in the three-plot comes down a lot.

The larger the RMSE index, the lower the validity of the model, and the higher the difference in the factor extracted from the land and the resulting model is increased and significant, and therefore the model will not have sufficient validity. In this community, in most of the indices the models obtained in 1×1 plots in both methods and in 2×2 plots in Method 2 are not valid enough. Because of this, the 1×1 plot was not suitable in this community, as the case with the 10-meter Sentinel bands. However, in the 1×2 plot and the three-plot method, the validity of this image (60 m resolution) is lower than the model's validity and is not statistically valid.

Community 2

In this community, most of the relationships of TSAVI1 and RVI were significant. In other words, in this community these two indices have good relations. As stated in the results section, with increasing plot area, in most cases the correlation coefficients increase and their significance increases. The correlation between sampling method 2 is less than sampling method 1. Correlation in 3×3 plots is significant in both sampling methods and in other plots is not or has low significance. In this community, 1×1, 1×2, and 2×2 plots, like the 10-meter bands, could not correlate well especially in the 60 m resolution image. Most of the indices of the models in the 3×3 meter plots are sufficiently valid. In community 1 and 2 the RVI index is a good index which is similar to some of the results of Zhang-Yu et al, 2007 and Smith et al, 1989.

Community 3

In this community, most of the relationships of NDVI and DVI were significant. Correlations in 1×1 and 1×2 plots in two sampling methods were not significant. Also the correlation between the two other plot sizes is not very high compared to the 10 m bands. Because, as in the other two communities studied, ground resolution is low (60×60) and sampling accuracy is reduced, especially in the three-plot method. In community 3 like the other two communities, the 2×2 and 3×3 plots were able to produce good results, and therefore the 2×2 plots could be suitable for similar situations due to ease of operation.

Examination of model validity test in community 3 shows that in most of the indices, the models obtained in 1×1 and 2×2 m plots in both sampling methods are not sufficiently valid. Sometimes the correlation of the indices with the production and canopy cover is high, but it does not mean that the index or sampling factors are appropriate because the correlation may be high but the resulting model may not be sufficiently valid. Therefore, the criterion for selecting the appropriate index and sampling factors is the validity of the model.

For plant production, the correlation and validity of the models were lower in both sampling methods compared to the 10×10 m Sentinel image bands. As can be seen, the vegetation indices in 1×1 and 1×2 plots in this community could not be correlated good and the resulting model is not sufficiently valid for the tests used. Although the 3×3 plot productions better results, the difference with the 2×2 plot is not statistically significant and it is possible to recommend a 2×2 plot to estimate production under similar conditions.

REFERENCES

1. Adamchuk. V Perk. R and Schepers. J. Application of remote sensing in site-specific management. Institute of agriculture and natural resources. University of Nebraska Cooperative Extension Precision Agriculture EC 2004, 04- 702.
2. Adams J.B., Smith M. O., and Gillespie A. R. Simple models for complex natural surfaces: a strategy for the hyperspectral era of remote sensing, in _Proc. IEEE Int. Geosci. And Remote Sensing Symp. '89_, IEEE, New York, 1989, 16-21.
3. Ahmadpour, A. Shukri, M. Suleimani, K. And the Victim, J. Investigation of Vegetation Communities Using Remote Sensing Methods (Case Study: Golwell and Serani Conservation Community), Journal of Range Research, Fourth Year No. 3, Fall 2010, 359-348.
4. Akbari, M. Evaluation and Classification by RS and GIS Techniques in Arid North Isfahan. M.Sc., Isfahan University of Technology, 2003.
5. Amiri F. Using Remote Sensing Data for Vegetation Cover Assessment in Semi-Arid Rangelands of Center Province of Iran. Would Applied Sciences Journal 2010, 11 (12): 1537-1546.
6. Anderson G L and Hanson. J D. Evaluating hand-help radiometer derived vegetation indices for estimating above ground biomass on semiarid rangelands. Remote Sensing of Environment journal 1993, 45: 165- 175.
7. Andrew, K. Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. Int. J of Remote Sensing of Environment, 2006, 100:321-334.
8. Arieira J D. Karssenberg S. M. De Jong E. A. Addink E. G. Nunes da Cunha and J. O. Skoien. Et al, Integrating field sampling, geostatistics and remote sensing to map Wetland vegetation in Panatal, Brazil. Bio geosciences Journal, 2011, 8, 667 -686.
9. Arzani, H and Abedi, M. Rangeland Recovery: Auditing and Monitoring, University of Tehran Publications, 2014, Vol I, 225 p.
10. Arzani, H. Dehdari, Sa. And King, G. Rangeland Production Estimation Models through Vegetation Measurement, Iranian Journal of Rangeland and Wildlife Research, 2011, 18(1): 16-1.
11. Barati S. Rayegani B. Saati M. Sharifi A. and Nasri M. Comparison the accuracies of different spectral indices for estimation of vegetation cover raction in sparse vegetated areas. The Egyptian Journal of Remote Sensing and Space Sciences, 2011, 14, 49–56.
12. Baret. F. and Buis. Estimating Canopy Characteristics from Remote Sensing Observations: Review of Methods and Associated Problems. Advances in Land Remote Sensing. 2008, 173-201.
13. Bo-Cai G. Marcos J. M. Curtiss O. D. Alexander F.H. G. Atmospheric correction algorithms for hyperspectral remote sensing data of land and ocean, Remote Sensing of Environment, 2009, S17-S24.
14. Bonham C D. Measurement for terrestrial vegetation. John wily and sons, Newyork, USA. 2013, 338.
15. Brinkman K. Dickhoefer U. Schlecht E. and Buekert A. Quantification of aboveground rangeland productivity and anthropogenic degradation on the Arabian Peninsula using Landsat imagery and field inventory data. Remote Sensing of Environment Journal 2011, 115: 465- 474.
16. Christina E. A. Claudia K & Stefan Dech. Derivation of biomass information for semi-arid areas using remote-sensing data. International Journal of Remote Sensing. 2012.
17. Emmanouil P. Nicholas D. Nicolas R. D. and Nikolaos V. S. The role of spatial and spectral resolution on the effectiveness of satellite-based vegetation indices. Remote Sensing for Agriculture, Ecosystems, and Hydrology XVIII, edited by Christopher M. U. Neale, Antonino Maltese, Proc. of SPIE Vol. 2016, 9998, 99981L.
18. Fei Y. Marvin E. B. Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery, Remote Sensing of Environment, 2007, 106(3), Pages 375-386.
19. Goswami S. Gamon J. A. Vargas S. Tweedie C. E. Relationships of NDVI, biomass and leaf area idex for six key plant species in Barrow Alaska. PeerJ PrePrints, CC-BY 4.0 Open Access. 2015.
20. Gyanesh Ch, Brian L. M, Dennis L. H. Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors, Remote Sensing of Environment, 2009, 113(5), Pages 893-903.
21. Hadian F. Bashari, H. And Jafari, R. Investigation of the effect of sampling level on correlation of canopy cover and NDVI

vegetation index. Journal of GIS Application in Natural Resources Sciences, 2013, 3(2), pp: 85-97.

22. Huete A. Remote sensing for Natural Resources Management and environmental Monitoring: Manual of remote sensing 3ed. 2004, 4. University of Arizona.
23. Jafari, F. Jafari, R. And Bashari, H. Rangeland performance using field and remote sensing approaches. Iranian Journal of Forests and Rangelands Conservation and Protection Research, 2015, 13(1), pp: 73-57.
24. JB Campbell, RH Wynne–. Introduction for remote sensing. The Guilford press. 2011, 667 pages.
25. Jin Y. Yang X. Qiu J. Li J. Gao T. Wu Q. Zhao F. Ma H. Yu H. and Xu B. et al Remote Sensing-Based Biomass Estimation and Its Spatio-Temporal Variations in Temperate Grassland, Northern China. Remote Sensing journal, 2014, 6, 1496-1513.
26. Jose A. J. B. Pablo J. Zarco-Tejada, Lola S, and Elias F. Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle. IEEE Transactions on Geoscience and Remote Sensing, 2009, V. 47, N. 3.
27. Kusuma P. Hively W.D. and McCarty W. Evaluating the relationship between biomass, percent groundcoverand remote sensing indices across six winter cover crop field's inMaryland, United States. International Journal of Applied Earth Observation and Geoinformation, 2015, 39, 88- 102.
28. Leonardo C.d.a. Romulo P. G. Carlos A.O.V. and Nerilson T.S. Analysis of sampling methods and its influence on image classification process of remotely sensed images through a qualitative approach. Anais XIV Simposio Brasileiro de Sensoriamento Remoto, Natal, brasil, 25-30 abril 2009, INPE, 2009, p. 6773-6780.
29. Lillesand M. T. Klefer W. R. and chipman N J. Rmote sensing and image interpretation (6th ed). John Wiley and Sons, Inc, New York. 2014.
30. Mather P. M. and Brandt Tso. Clasification methods for remotely sensed data. CRC press, Taylor and Francis group. 2016, 356 p.
31. Monitoring vegetation systems in the Great Plains with ERTS. Third ERTS Symposium, NASA SP-351. 1:309-317.
32. Mousavi, A. Farahpour, M. Shukri, M. Soleimani K. and Goodarzi, M. Investigating the Trends of Vegetation Mass Change in Part of Lar Dam Basin over a 25-Year Period Using Integrated GIS and RS, Iranian Journal of Range and Desert Research, 2006, Vol 13, Number 3, pp. 186-200.
33. Pickup, G., Chewings, V. H. and Nelson, O. J. Estimating changes in vegetation cover over time in arid rangelands using Landsat MSS data. Remote Sensing of Environment. 1993, 43:243-263.
34. Qi J. Chehbouni A. Huete A. R. Kerr Y. H. and Sorooshian S. A modified soil adjusted vegetation index. Remote Sensing of Environment journal, 1994, 48: 119- 126.
35. Robert C. M. Jiaguo Q. Philip H.Sharon H. B. Carolyn M. W. Saud A.Mark W. David G. and Roseann M. e Remote Sensing for Grassland Management in the Arid Southwest. Rangeland Ecol Manage, 2006, 59:530–540.
36. Rozenstein O. and Karnieli A. Comparison of methods for land-use classification incorporating remote sensing and GIS inputs, Applied Geography, 2011, Vol 31, Issue 2, Pages 533-544.
37. Sam J. Purkis, Victor V. Klemas. Remote Sensing and Global Environmental Change. 2011, 261 pages.
38. Thorp K. R. French A. N. and Rango. A. Effects of image spatial and spectral characteristics on mapping semiarid rangelands vegetation using multiple end member spectral mixture analysis (MESMA). Remote Sensing of Environment journal, 2013, 132: 120- 130.
39. YU Long Z. Li LIU W. and ZHOU Hua-Kun. Using Remote Sensing and GIS Technologies to Estimate Grass Production and Livestock Carrying Capacity of Alpine Grasslands in Golog Prefecture, China. Elsevier Limited Science Press, Pedosphere 2010, 20 (3): 342-351.
40. www.Usgs.gov
41. www.calforests.org/glossary.html
42. www.waterquality.de/hydrobio.hw/rterms.htm
43. www.essex.ac.uk/g2gp/gis/sect101.asp