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Biophysical Indices Derived From High Resolution Satellite Images For Monitoring Rangelands In Swaida-Badia/Syria

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Abstract

Changes in vegetation condition impact rangeland resources in arid and semiarid areas, also human activities have a major impact on these resources either positive through planning and investment or negative through overgrazing, wood cutting and crises. Remote sensing technology provide an opportunity for monitoring rangeland biophysical attributes and changes in biomass and plant productivity during the growing season which could a chive sustainable management. This study aimed to evaluate the vegetation dynamics and assess rangelands condition during the growing season in Swaida Rangelands Badia using biophysical indices derived from Sentinel-2 satellite images. Biophysical indices including leaf area index (LAI), canopy chlorophyll content (CCC), canopy water content (CWC), fraction of absorbed photosynthetically active radiation (FAPAR), and fraction canopy cover (FCOVER) were derived, spectrally, from Sentinel-2 high resolution images. Sentinel-2 satellite images acquired at March, April and May during 2017 growing season was used in the process and analysis. Methodology of integration the biophysical indices, spectrally are formatted to study the vegetative cover status in rangeland of Swaida-badia, so generalization it for all Syrian Badia. Biophysical spectral indices depending on the suggested methodology were observed the status of vegetative cover according to its distribution and area. Also, record the linear increasing of LAI values in Swaida-badia from Marsh to April up to May. While chlorophyll concentration (CCC) and water content (CWC) increased from Marsh to April and decreased in May. Fraction absorbed photosynthesis active radiation (FAPAR) decreased slowly from Marsh to April up to

May. Spectral growth curves for different rangeland vegetation conditions classes that observed in the Swaida Badia integrate the management process of rangeland between areas.

Key words: Biophysical indices, satellite images, Sentinel-2, vegetative cover, Badia rangelands, Syria.

Introduction

Rangelands represent an important resource in the national income of most of the Arab countries as they cover large areas (about 33 % of the Arab countries area) and participate in the Arabian food security. Rangelands in Syria have been major sources of income for large portion of the country population. In Syria, the rangelands cover some 57% of the country territory (18.5 million hectares). About 10 million hectares usually receiving less than 200 mm precipitation/year. It is nearly totally devoted to grazing and browsing. Most depressions and wadi beds that receive extra water from run-of were still cropped until recently with barley, or even wheat (Mohamed et al., 2019). Changes in the natural vegetation conditions impact rangeland resources in arid and semiarid areas, also human activities have a major impact on this resource either positive through planning and investment or negative through overgrazing, wood cutting and crises. Rangeland and grassland conditions directly affect forage quality, livestock production, and regional grassland resources (Wang et al., 2019).

Remote sensing technology provide an opportunity for monitoring rangeland biophysical attributes and changes in biomass and plant productivity during the growing season which could have valuable application in implemented sustainable natural resources management plans. Recent advances in the technology have produced innovative remote sensing sensors with increasing spatial and temporal resolution of globally available satellite images such as those provided by Sentinel-2, creating new opportunities for environmental monitoring and generating accurate datasets (Belgiu et al., 2018).

The Sentinel-2 mission has been improving existing Earth observation capabilities with sensors that have several advantageous spectral, spatial, and temporal characteristics, compared to current satellite systems (Liu et al., 2018). High resolution maps to evaluate vegetation dynamics can be produced using Sentinel-2 satellite imagery (Eklundh et al., 2012). Studies have suggested the use of NDVI to evaluate vegetation condition from Sentinel-2 images (Eklundh et al., 2012;

Tian et al., 2016; Zhang et al., 2017); however, under desert and arid rangelands other vegetation indices would be more accurate. Biophysical indices are the most importance of vegetative indices in studying plant status and can contribute in growth analysis and process the rangelands management of vegetative covers along time series in arid zones. Vegetation indices derived from the spectral bands of the MSI Sentinel-2 sensor provide quantitative indicators of the green biomass status in natural grasslands, also, the free Sentinel 2 satellites data showed considerable potential for studies and research related to grasslands productivity, management, monitoring and conservation (Darvishzadeh et al., 2019; Filho et al., 2020).

Sentinel-2 satellite provide images that can be used to distinguish different crop types, monitor plant growth, and retrieve biophysical parameters, such as data on numerous plant indices, including the leaf area index, leaf chlorophyll content, and leaf water content (Clevers and Gitelson, 2013; Schlemmer et al., 2013; Hill, 2013; Frampton et al., 2013; Verrelst et al., 2015). For instance, Korhonen et al., (2017) used Sentinel-2 satellite images to estimate the boreal forest canopy cover and leaf area index; Moreover, Shoko and Mutanga, (2017) tested the ability of sentinel 2 MSI sensor in detecting and discriminating differences between C3 and C4 grass species. It was concluded that sub-weekly biophysical variables (LAI, FCOVER, FAPAR, CCC, and CWC) derived from medium resolution (20 m) of Sentinel-2 imagery could be estimated with reasonable uncertainties and accuracies and can be used to asses agricultural vegetation (Djamai et al., 2019). Biophysical indices could contribute in growth analysis and monitoring vegetation changes during the growing season and over years, which could have practical application in the sustainable rangelands management particularly evaluating vegetation covers along time series of zone. This could minimize the gap in the need to monitor the rapid change in the vegetation health and condition, as a result of plant growth, drought and water stress, management practices, pests and disease, and other human activities (European Space Agency, 2019). The objective of this research was to study the vegetation dynamics and assessment of rangelands condition during the growing season in Swaida Rangelands Badia using biophysical indices derived from Sentinel-2 satellite images to contribute to the development and management of arid rangelands in the Arab region.

Material and Methods

Study area

The study area represents the part of Syrian Badia of the Swaida governorate which named Swaida-Badia (figure 1). Table (1) shows area of Swaida-Badia (2492.3 km^2) which cover 2.4% of Syrian Badia and 39.3% of Swaida governorate. Where Syrian Badia cover more than 57% of Syria area. Swaida governorate plotted under 5 rain stable zones of Syrian bioclimate (figure 2), but Swaida Rangelands Badia occupied zones 5, 4 and partly 3, that is meaning the average annual precipitation for those zones area about less than 150, 150-250, and 250-300 mm, respectively. However, most of the study area is located in the zones with annual average precipitation in the area is less than 200 mm. The topographic landscape of Swaida-Badia ranged from 550-1200 m above sea level and slop from west to east (figure 3). Basalt occupied large areas in the Swaida Governorate. The major soil type in the Swaida Rangelands Badia is Lithic Torriorthents and soil texture of the area is loam to silty clay.

Rangelands vegetation in the study area includes perennial shrubs, perennial grasses, and annual forbs and grasses. The primary shrubs species common in the study area are *Atriplex halimus, Atriplex leucoclada, Salsola vermiculata, Artemisia herba-alba, Anavasis syriaca, Achillea fragrantissima*, and *Astragalus spinosus*. Annual average forage production in this rangelands type range from about 48 kg/ha to 204 kg/ha usually half of this amount produced by palatable perennial shrubs (ACSAD, 2004). Plant cover ranged from 11 to 20 % and in general rangelands condition in the area is in poor to fair condition.

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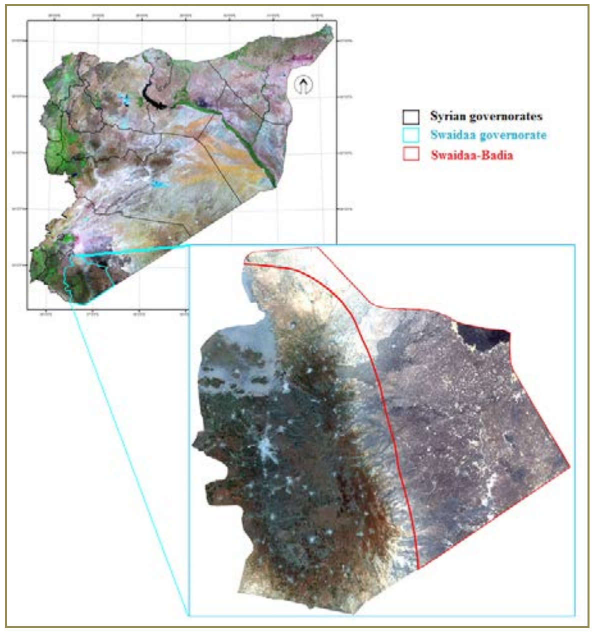
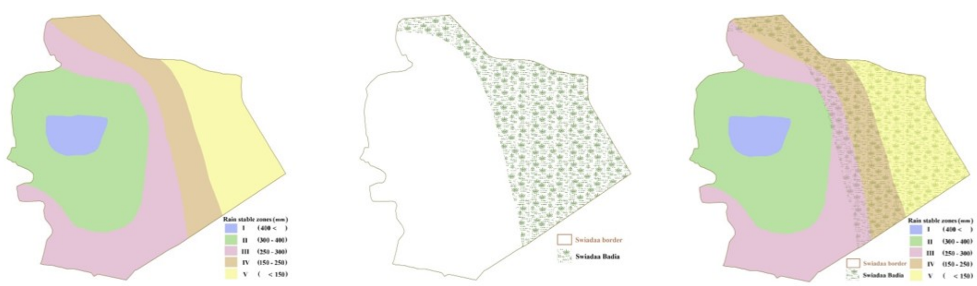


Figure (1) Swaida Governorate and its Rangelands Badia on Sentinel-2 images of Syria

Table (1), Area and percent of Badia, Swaida-Badia from Syria

	Syria	Badia	Swaida	Swaida-Badia
Area (km^2):	185180	105719	6337.5	2492.3
% Badia of:	57.1			
% Swaida of:	3.4			
% Swaida-Badia of:	1.3	2.4	39.3	



Rain stable zones in Swaida — Swaida Rangelands Badia — Rain stable zones opposite Badia

Figure (2) Rain stable zones in Swaida opposite Badia

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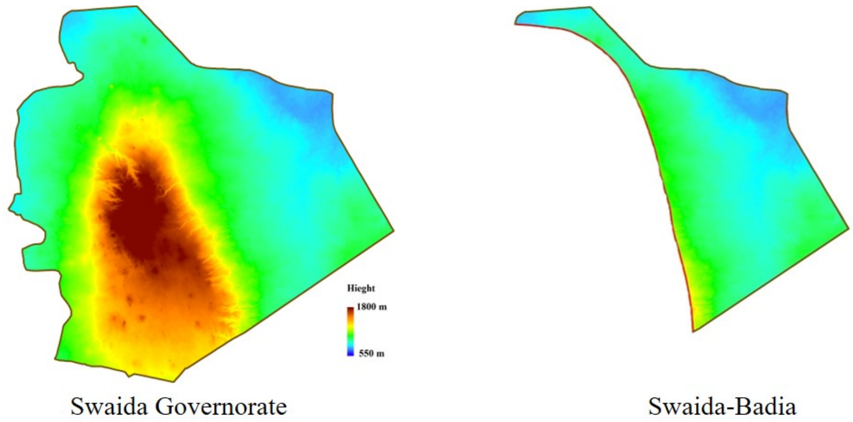

Figure (3) Digital Elevation Model (DEM) map of Swaida and its Rangelands Badia

Data and software

Sentinel-2 is a multi-spectral imaging mission, which supports the Copernicus Land Monitoring studies by the European Space Agency and became operational in late 2015. The revisit time of one single satellite is 10 days and for the combined constellation the revisit time is 5 days, making it a good tool for time series studies. Sentinel-2 data can be acquired freely and available online through the Copernicus programme of ESA, via https://scihub.copernicus.eu/. SNAP, ERDAS imagine, and ArcGIS software programs were used in processing and formatted the images data. Swaida governorate is covered by 4 scenes of Sentinel-2 images for each specific date due to plotted at corner of 4 scenes by Sentinel cover index as presented in figure (4). Then, 12 images for three dates coverage were acquired. Images coverage extend March, April and May of 2017 growing season. Images date and named by sentinel are rewrite in table (2).

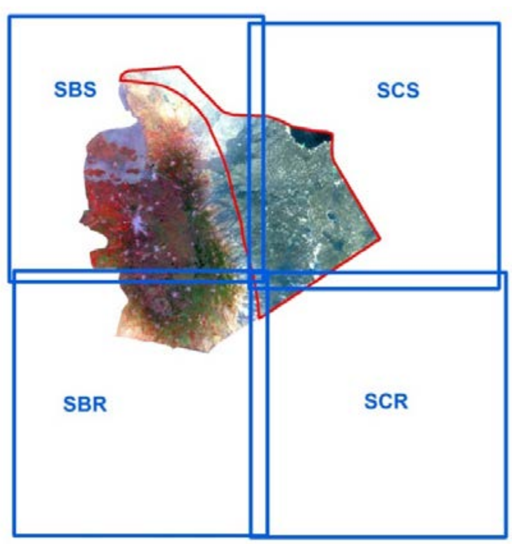

Figure (4) Sentinel-2 images Index cover the Swaida governorate, Syria.

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Table (2) Images date and name by Sentinel over Swaida governorate that was used in this study.

SN	Date	Image code
1	20170309	S2A_MSIL1C_20170309T080741_N0204_R078_T37SBR_20170309T081438
2	20170309	S2A_MSIL1C_20170309T080741_N0204_R078_T37SBS_20170309T081438
3	20170309	S2A_MSIL1C_20170309T080741_N0204_R078_T37SCR_20170309T081438
4	20170309	S2A_MSIL1C_20170309T080741_N0204_R078_T37SCS_20170309T081438
5	20170418	S2A_MSIL1C_20170418T080611_N0204_R078_T37SBR_20170418T081149
6	20170418	S2A_MSIL1C_20170418T080611_N0204_R078_T37SBS_20170418T081149
7	20170418	S2A_MSIL1C_20170418T080611_N0204_R078_T37SCR_20170418T081149
8	20170418	S2A_MSIL1C_20170418T080611_N0204_R078_T37SCS_20170418T081149
9	20170528	S2A_MSIL1C_20170528T080611_N0205_R078_T37SBR_20170528T081043
10	20170528	S2A_MSIL1C_20170528T080611_N0205_R078_T37SBS_20170528T081043
11	20170528	S2A_MSIL1C_20170528T080611_N0205_R078_T37SCR_20170528T081043
12	20170528	S2A_MSIL1C_20170528T080611_N0205_R078_T37SCS_20170528T081043

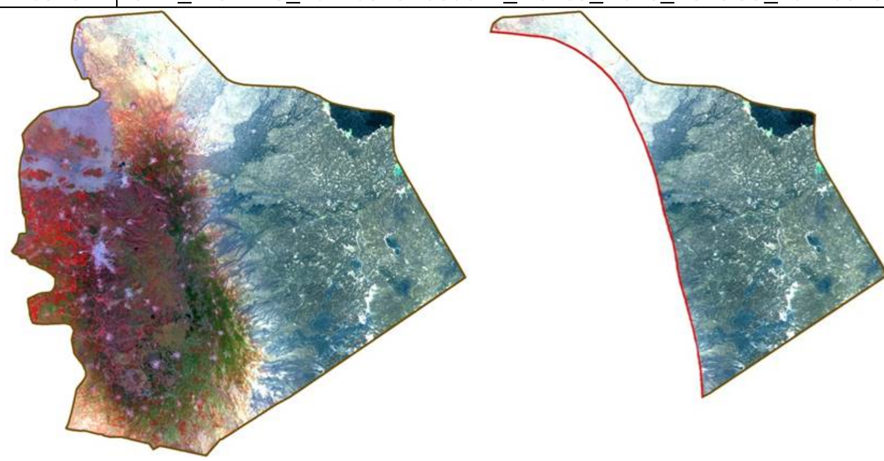

Figure (5) Sentinel images (RGB=bands 8, 4, 3) cover Swaida governorate and the Swaida Rangelands Badia at 18/4/2017

Estimation of vegetation biophysical variables

The methods used during the research are summarized and presented in figure (6). The processed product type that is made available to users is Level-1B. From top-of-canopy normalized reflectance data (Level-2B). Vegetation biophysical variables from each Sentinel-2 image were estimated using SNAP software package, these variables included LAI, FCOVER, FAPAR, CCC and CWC. LAI (Leaf area index): is a quantitative measure of the amount of live green leaf material present in the canopy per unit ground surface. It is defined as half of the total green leaf area per unit ground surface. FAPAR (Fraction of Absorbed Photo-synthetically Active Radiation): define as fraction of radiation absorbed by the photosynthesizing tissue in a canopy and estimated as a percentage, FCOVER (Fraction of vegetation cover) estimated as a percentage, CCC (Canopy Chlorophyll Content in the leaf) estimated as g/m^2, CWC (Canopy Water Content) estimated as kg/m^2.

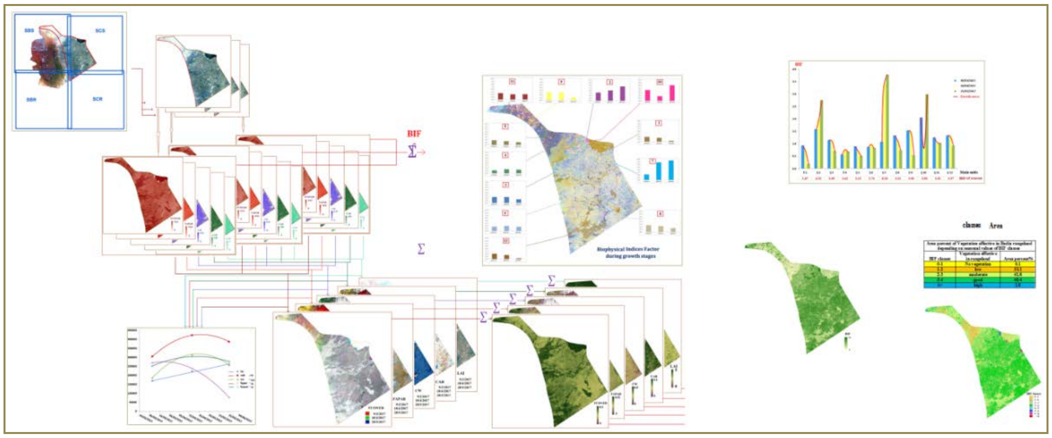

Figure (6) Flowchart of Sentinel-2 images analyses and the study methodology to evaluate rangeland vegetation condition

Results and Discussion

Biophysical variables in the Swaida Rangelands Badia during growth stages

Leaf Area Index

Figure (7) illustrates Leaf Area Index (LAI) over Swaida Rangelands Badia during the growth season of 2017 at main stages of three-months March, April and May. Figure (8) shows positive linear of LAI from March up to May. It means that the plant cover has increased in intercept with the sun light actively from March up to May. Figures (9) and (10) show the LAI progression during growth stages as RGB color map and the accumulated LAI during the growing season from March to May of 2017. Spectral reference and vegetation indices obtained from optical satellites are the most frequently used data to derive LAI of terrestrial ecosystems (Verrelst et al., 2012; Djamai et al., 2019). Our findings indicated that LAI could be useful biophysical variable for monitoring rangelands vegetation dynamics during the growing seasons; similar results also were obtained and reported by Wang et al., (2019); Darvishzadeh et al., (2019). LAI is important plant biophysical parameter which provides valuable information on vegetation structure and functioning (Jonckheere et al., 2004; García-Haro et al., 2018), and it is highly related to ecosystems productivity and energy mass exchange (Baret and Buis, 2008), hence it could contribute to vegetation evaluation and generating relevant biodiversity information.

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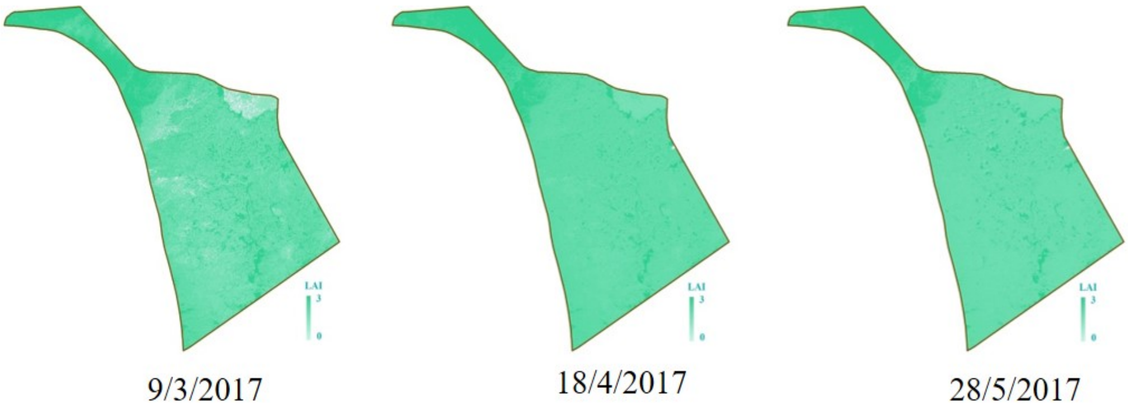


Figure (7) LAI during growth stages of the Swaida Rangelands Badia

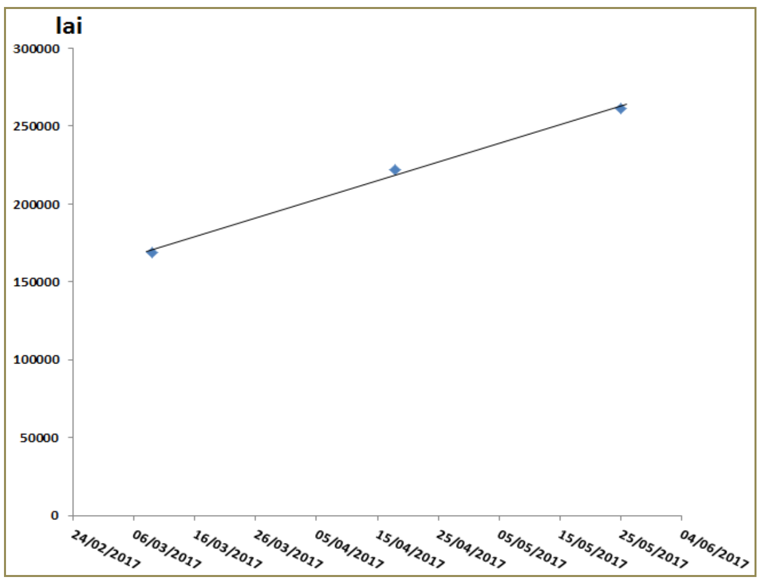


Figure (8) Summation LAI during each growth stage of the Swaida Rangelands Badia

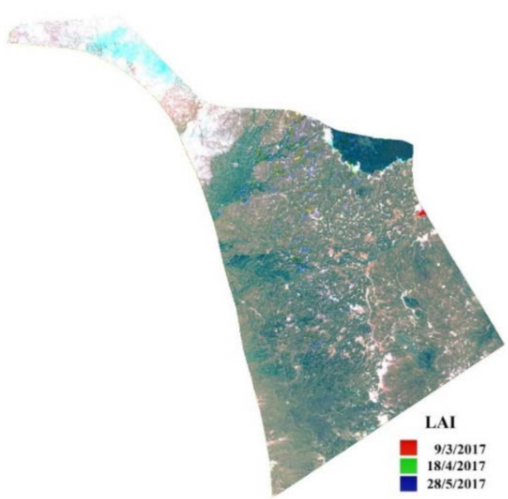
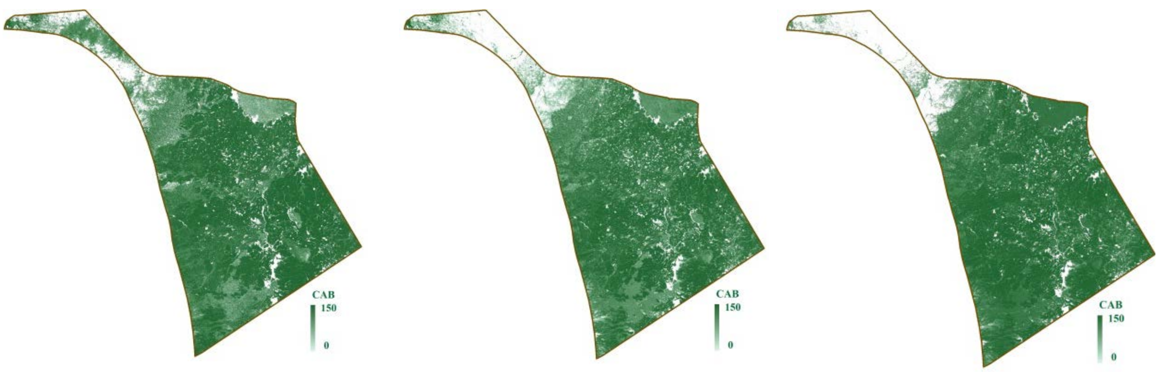


Figure (9), LAI progression during growth stages (RGB=bands 3/9, 4/18, 5/25/2017)

Figure (10), LAI accumulation of growth stages

Canopy Chlorophyll Content

Figure (11) illustrate the Canopy Chlorophyll Content in the leaf (CCC) over the Swaida Rangelands Badia during the growth season of 2017 at the main stages of the three-month March, April and May. Figure (12) show a slight increase of CCC from March to April and slight decrease from April to May. The maximum CCC values were obtained during April, 2017. Figures (13) and (14) present the CCC progression during growth stages as RGB color map and the accumulated CCC during the growing season from March to May of 2017. Djamai et al., (2019) also reported that Sentinel-2 satellite imagery was used to generate canopy chlorophyll content values with reasonable accuracy, which could provide essential information regarding the vegetation condition.



9/3/2017 **18/4/2017** **28/5/2017**

Figure (11), CCC during growth stages of the Swaida Rangelands Badia

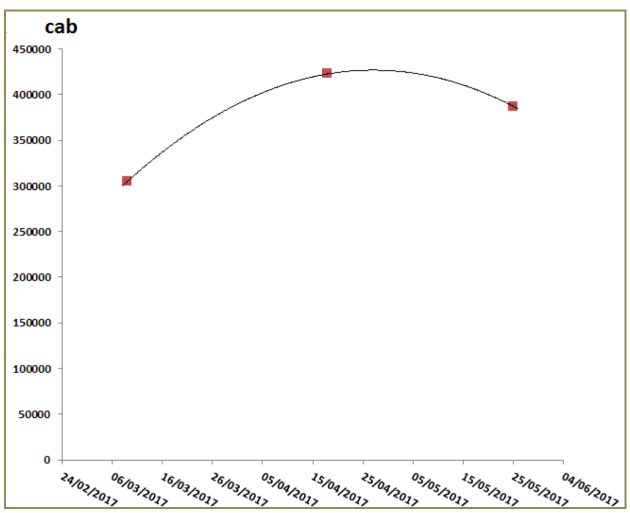


Figure (12) Summation CCC during each growth stage of the Swaida Rangelands Badia

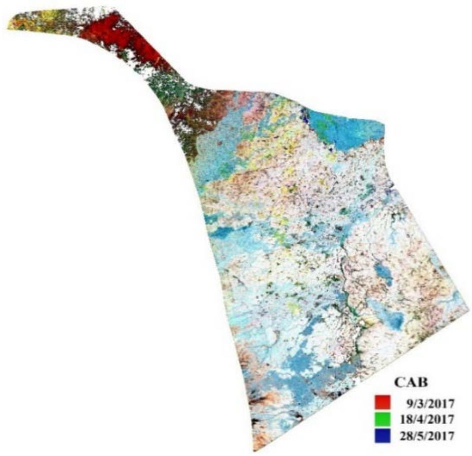
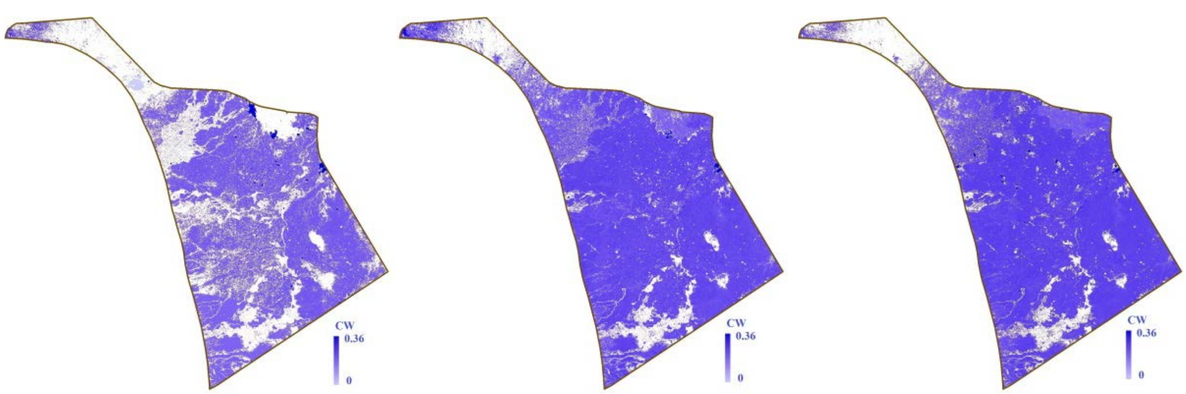


Figure (13) CCC progression during growth stages (RGB=bands 3/9, 4/18, 5/25/2017)

Figure (14) CCC accumulation of growth stages

Canopy Water Content (CWC)

Figure (15) illustrate the Canopy Water Content (CWC) over Swaida Rangelands Badia during growth season at main stages of three-month March, April and May. Figure (16) show the increased of CWC from March to April and after that decreased at May. That is mean the maximum vigor of the vegetative growth tack place at April in Swaida-Badia. But some small areas have more CWC than others at March which associated with bottom of hills. Some areas in the Swaida Rangelands Badia were recorded low of CWC during three months due to fragile of plant cover. Figures (17) and (18) show the CWC progression during growth stages as RGB color map and the accumulated CWC during the growing season from March to May of 2017.



9/3/2017 **18/4/2017** **28/5/2017**

Figure (15) CWC during growth stages of the Swaida Rangelands Badia

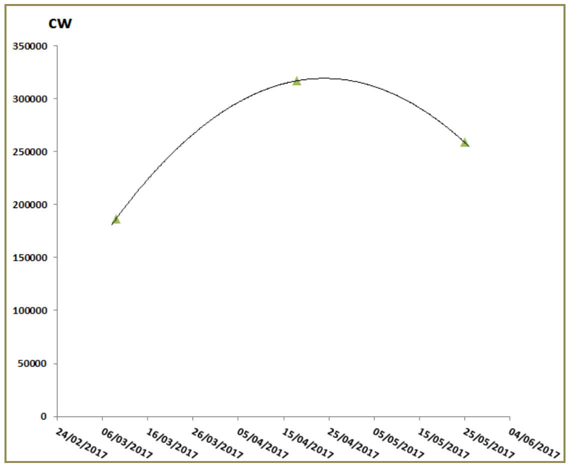


Figure (16), summation CWC during each growth stage of the Swaida Rangelands Badia

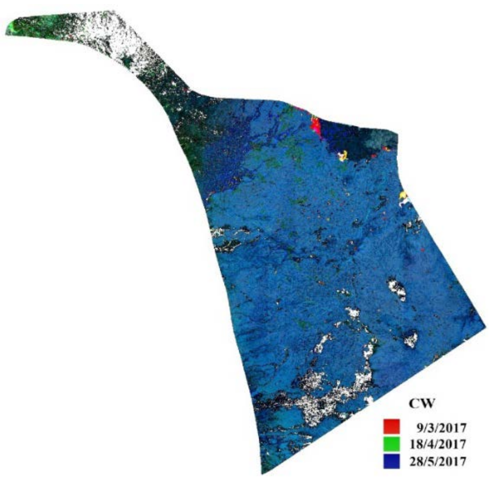


Figure (17) CWC progression during growth stages (RGB=bands 3/9, 4/18, 5/25/2017)

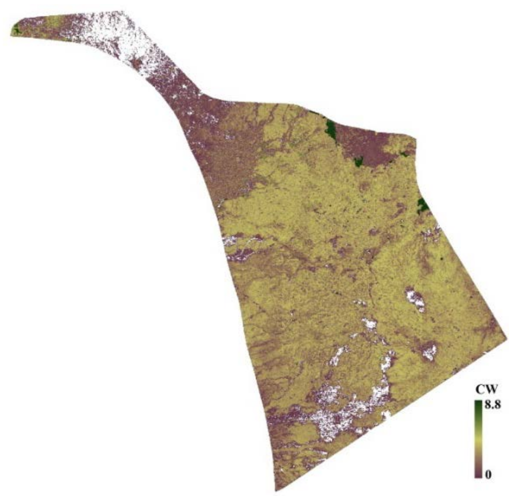


Figure (18) CWC accumulation of growth stages

Fraction of Absorbed Photosynthetically Active Radiation

Figure (19) illustrate the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) over Swaida-Badia during growth season at main stages of three-month March, April and May. Figure (20) show a slight decrease of FAPAR from March to April but quick decrease from April to May. That is mean the plant winter growth dominates with short vegetative time in the region, and another some plant growth patterns. Figures (21) and (22) present the FAPAR progression during growth stages as RGB color map and the accumulated FAPAR during the growing season from March to May of 2017.

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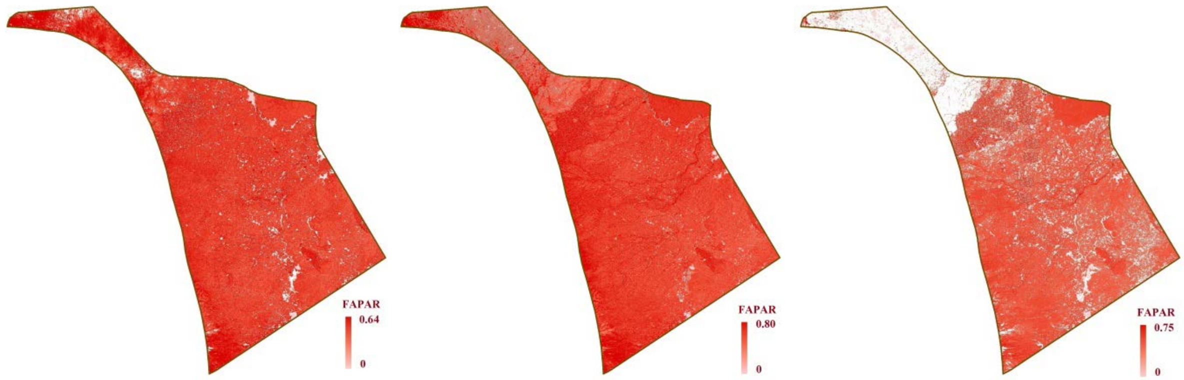

9/3/2017 **18/4/2017** **28/5/2017**

Figure (19) FAPAR during growth stages of the Swaida Rangelands Badia

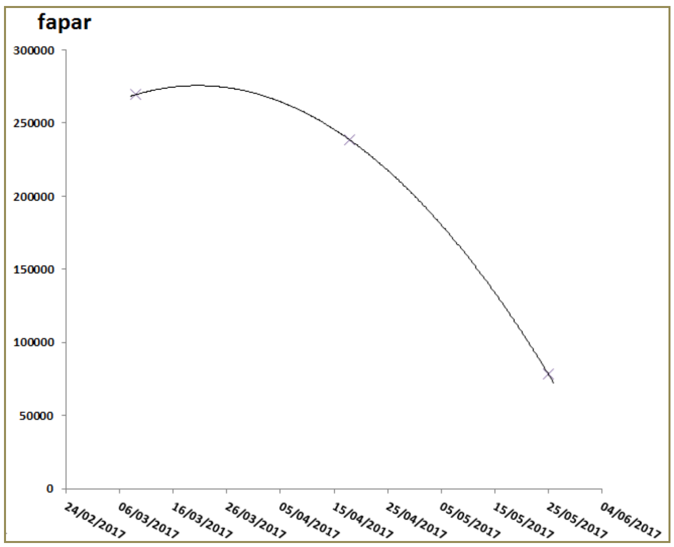

Figure (20) Summation FAPAR during each growth stage of the Swaida Rangelands Badia

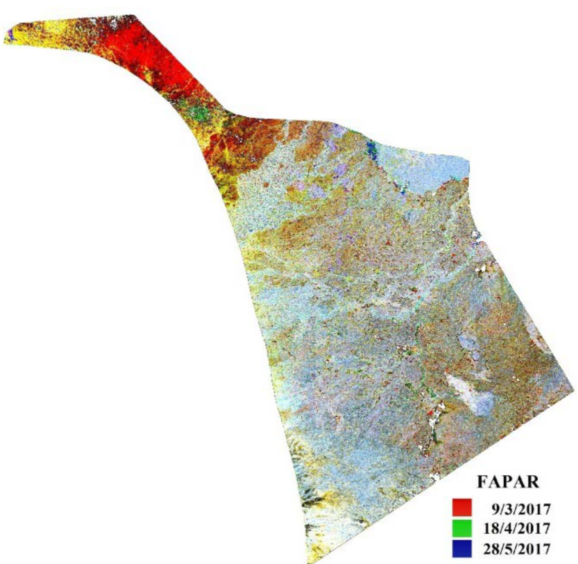

Figure (21) FAPAR progression during growth stages (RGB=bands 3/9, 4/18, 5/25/2017)

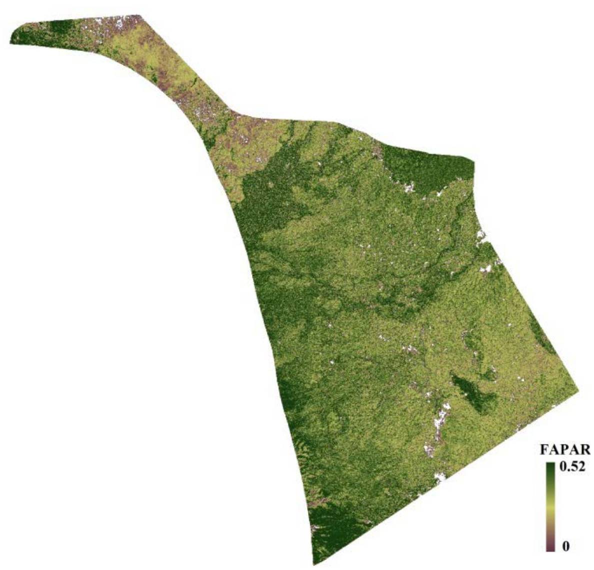

Figure (22) FAPAR accumulation of growth stages

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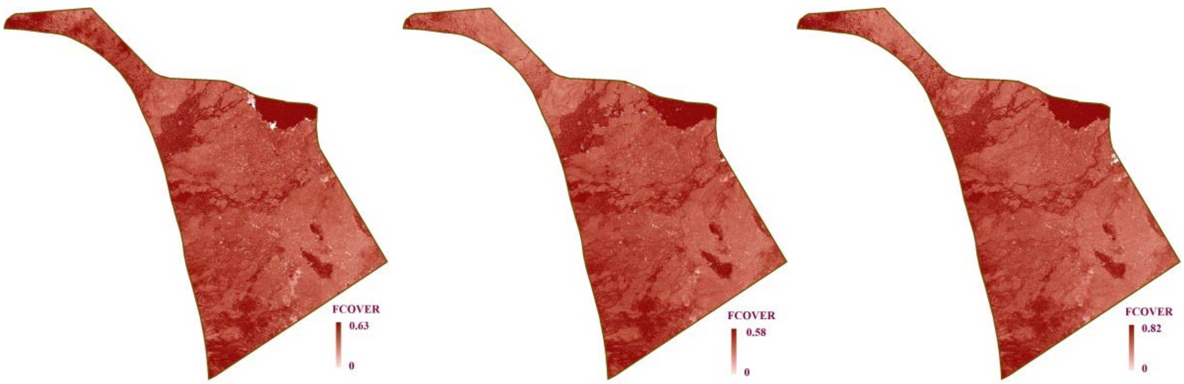
Fraction of vegetation cover

Figure (23) illustrate the Fraction of vegetation cover (FCOVER) over Swaida-Badia during growth season at main stages of three-month March, April and May. Figure (24) show a slight increase of FCOVER from March to April and slight decrease from April to May, which was similar to CCC curve. Figures (25) and (26) present the FCOVER progression during growth stages as RGB color map and the accumulated FCOVER during the growing season from March to May of 2017.



9/3/2017 **18/4/2017** **28/5/2017**

Figure (23) FCOVER during growth stages of the Swaida Rangelands Badia

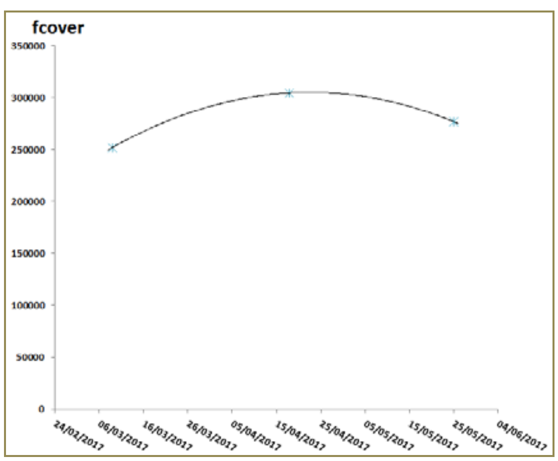


Figure (24) Summation FCOVER during each growth stage of the Swaida Rangelands Badia

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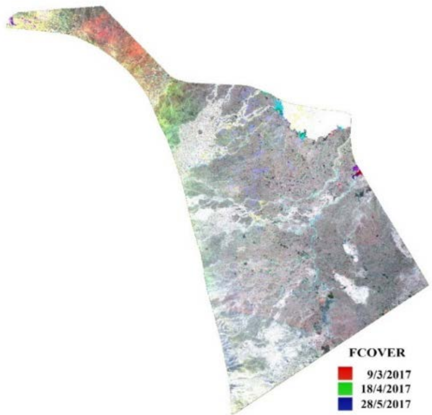

Figure (25), FCOVER progression during growth stages (RGB=bands 3/9, 4/18, 5/25/2017)

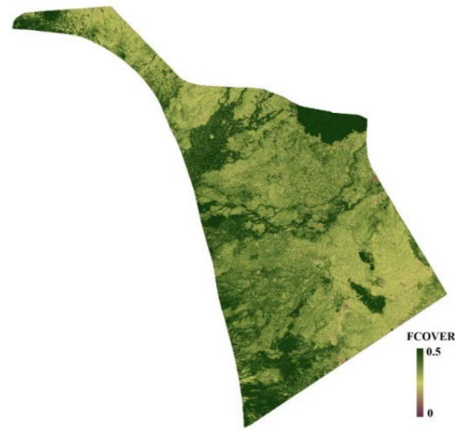

Figure (26), FCOVER accumulation of growth stages

Biophysical Indices Factor during growth stages

Figure (27) show Biophysical indices during each growth stages of Swaida-Badia. Some indices were rescaled due to easily direct compare between curves, as recorded for each index. CWC and CCC have similar trend which increased from March to April and after that decreased at May. Also, FCOVER have similar slight trend for both. FAPAR were decreased compare with increased of LAI from March to May, also, with increased CCC, CWC, and FCOVER from March to April during growing season. That is meaning, there is capability to increase the FAPAR then the dry matter of rangeland in this region on April, at less. These results of combining the different vegetation biophysical variables could be used for monitoring vegetation health and condition and detect changes in response to climate, grazing, and human activities. The accuracies of these biophysical indices were acceptable as reported by Djamai et al., (2019) who stated that results confirmed that time series of vegetation biophysical variables (LAI, CCC, CWC, FCOVER, and FAPAR) could be estimated with reasonable uncertainties and accuracies.

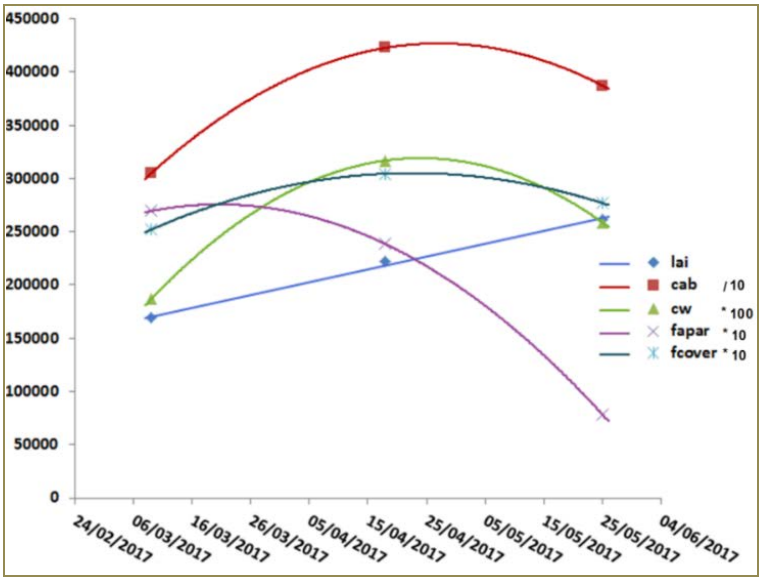

Figure (27) Summation each Biophysical index (after rescaled) during each growth stages of the Swaida Rangelands Badia

For each unit area (pixel), the five biophysical indices were accumulated as of Biophysical Indices Factor (BIF) due to mapping the growth types and main rangeland units in the Swaida-Badia. BIF was calculated by the following equation as suggested by the authors:

$$BIF = LAI + CCC/10 + CWC*10 + FAPAR + FCOVER$$

[where: each biophysical index > 0]

Which, some indices were weighted for combination the in equation. Figure (28) show a composite image of BIF stages (R=3/9, G=4/18, B=5/28/2017) of Swaida-Badia.

It is clear that ice (yellow) has a different spectral response than dirty ice (red) and snow (purple). This can be seen in the intensity of the response, but also in the shape of the response. Snow responds different than ice between 700 – 900 nm, with the peak shift at 842 nm in particular, as shown with the blue arrows in figure (29). However, the bands before 842 nm also exhibit slightly different behaviour. Biophysical Indices Factor during season of the Swaida Rangelands Badia are presented in figure (30), and figure (31) show the reclassified rangelands vegetation map based on the Biophysical Indices Factor during season of the Swaida Rangelands Badia.

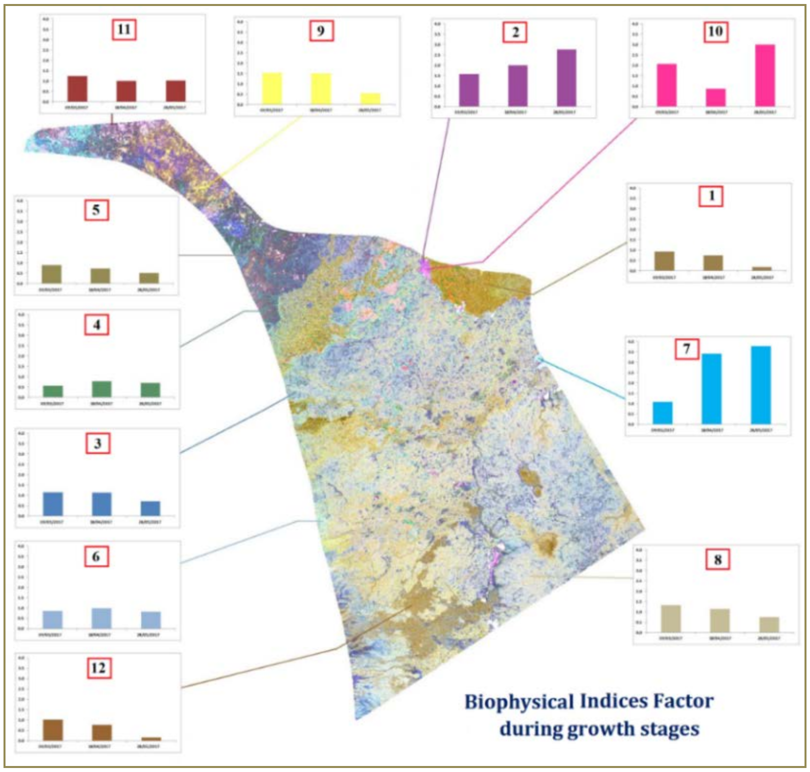

Figure (28) Biophysical Indices Factor during each growth stages of the Swaida Rangelands Badia

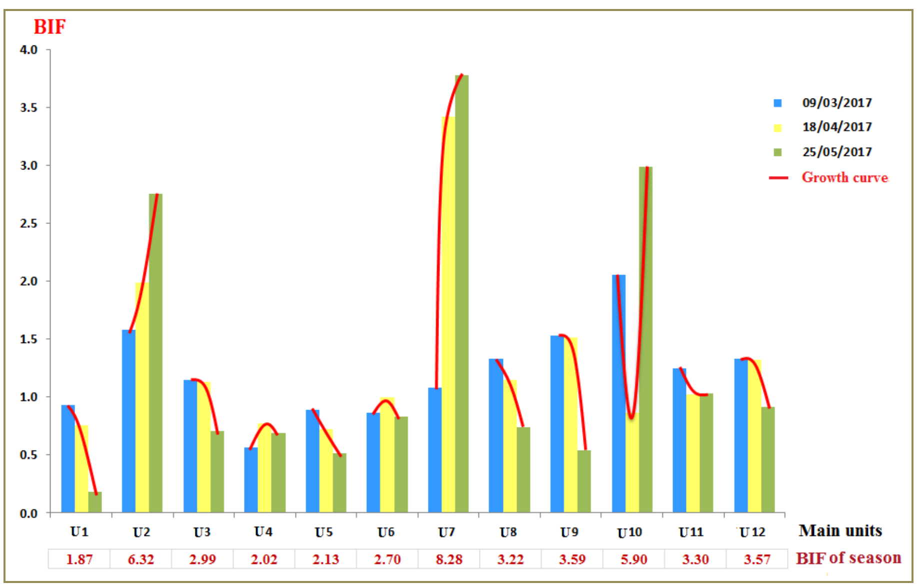

Figure (29) Biophysical Indices Factor during growth stages of main units in the Swaida Rangelands Badia

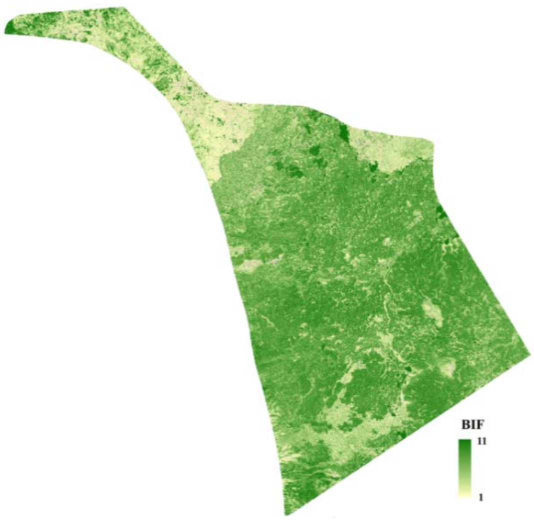

Figure (30) Biophysical Indices Factor during season of the Swaida Rangelands Badia

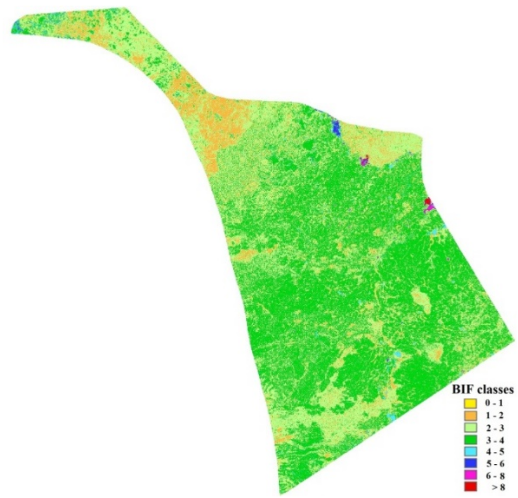

Figure (31) reclassified the Biophysical Indices Factor during season of the Swaida Rangelands Badia

Data presented in table (3) show the classified vegetation classes of the Swaida Rangelands Badia study area at spring 2017. These data were generated from the classified map which was produce using the five biophysical indices. Results indicated that about 52 % of the area was in low to moderate vegetation condition, and about 48 % of the study area was in good rangelands vegetation condition.

Table (3) Area percent of Vegetation effective in Badia rangeland depending on seasonal values of BIF classes

BIF classes	Vegetation effective in rangelands	Area percent %
0-1	No vegetation	0.1
1-2	low	10.1
2-3	moderate	41.6
3-4	good	46.4
4 <	high	1.8

Conclusion

Biophysical variables including, LAI, CCC, CWC, FCOVER, and FAPAR were derived from Sentinel-2 satellite images for the Swaida Rangelands Badia during three months period of the primary growing season. LAI showed liner increase from March to May of 2017, while CCC and CWC increased in the period from March to April and then decreased toward May. Biophysical indices were used to develop spectral growth curves and evaluate and classify Swaida rangeland Badia to the different vegetation conditions classes that observed in the study area. Results indicated that about 52 % of the area was in low to moderate vegetation condition, and about 48 % of the study area was in good rangelands vegetation condition.

The approach developed in this paper have the potential for estimation of biophysical variables at a higher spatial resolution, which would greatly increase their use and application for arid rangelands vegetation monitoring and assessments and for rangelands management applications.

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