NCARE

"Regional Cooperation on Improved Water Resources Management and Capacity Building Program"

Drought Analysis using MODIS NDVI 250 m time series for Mafraq area - season 2013/2014.

Prepared by

Eng. Muna Saba
Supervisor of Drought Monitoring Unit
NCARE - Jordan

Hashemite Kingdom of Jordan
Ministry of Water and Irrigation

USAID FROM THE AMERICAN PEOPLE

NASA

Drought Analysis using MODIS NDVI 250 m time series for Mafraq area - season 2013/2014.

Prepared by

Muna Saba

Supervisor of Drought Monitoring Unit/ NCARE - Jordan

Introduction:

This study is part of the participation of NCARE/ Jordan in Drought Monitoring Component the "Regional Cooperation on Improved Water Resources Management and Capacity Building Program". The program is sponsored by the World Bank- Middle East North Africa (MENA) to achieve improved water resources management and planning across the Mediterranean countries: Egypt, Jordan, Lebanon, Morocco and Tunisia.

Drought Monitoring Component

The goal of this component was to develop early warning indicators using MODIS long record as vegetation monitoring indicators including "standardized vegetation index, vegetation condition index, temperature condition index, vegetation health index, vegetation drought index, water stress vegetation index" with the support of daily ALEXI ET maps provided by NASA, as well as the integration of the TRMM satellite precipitation.

NCARE here presents its share of the ongoing research in drought monitoring. The following analysis put forward the MODIS NDVI and different model as potential drought indicators, particularly for northeast Jordan (Mafraq study area).

Drought monitoring

Drought monitoring comes with a high priority in Jordan. The country already suffers from high rainfall variability in both amount and distribution. The drought impact is expected to increase especially with the expected decrease in precipitation due to climate change. Monitoring of vegetation using time series of satellite data can assist in understanding the variation both annual and inter-annually.

Most monitoring of large scale vegetation is based on the normalized vegetation difference index (NDVI) time series datasets. The Normalized Difference Vegetation Index (NDVI) gives a measure of the vegetative cover on the land surface over wide areas. Vegetation differs from other land surfaces because it tends to absorb strongly the red wavelengths of sunlight and reflect in the near-infrared wavelengths.

The Normalized Difference Vegetation Index (NDVI) is a measure of the difference in reflectance between these wavelength ranges.

$$NDVI = (NIR - RED) / (NIR + RED)$$

The Moderate Resolution Imaging Spectroradiometer (MODIS) well-calibrated sensor was launched in December 1999. Global MODIS vegetation indices are designed to provide consistent spatial and temporal comparisons of vegetation conditions. The MODIS NDVI products are computed from atmospherically corrected bi-directional surface reflectances that have been masked for water, clouds, heavy aerosols, and cloud shadows.

Global MOD13Q1 data "MODIS/TERRA VEGEGTATION INDICES 16-DAY L3 GLOBAL 250 m SIN GRID V005" are provided every 16 days at 250-meter spatial resolution as a gridded level-3 product in the Sinusoidal projection.

MODIS 16-day Composite Vegetation Index Reference Calendar			
MODIS Period	**Julian Day Range**	**Calendar Day (regular) '01,'02,'03,'05,'06,'07,'09,'10**	**Calendar Day (leap) '00,'04,'08,'12**
1	1- 16	Jan 01 - 16	Jan 01 - 16
2	17 - 32	Jan 17 - 01 Feb	Jan 17 - 01 Feb
3	33 - 48	Feb 02 - Feb 17	Feb 02 - Feb 17
4	49 - 64	Feb 18 - 05 Mar	Feb 18 - 04 Mar
5	65 - 80	Mar 06 - 21	Mar 05 - 20
6	81 - 96	Mar 22 - 06 Apr	Mar 21 - 05 Apr
7	97 - 112	Apr 07 - 22	Apr 6 - 21
8	113 - 128	Apr 23 - 08 May	Apr 22 - 07 May
9	129 - 144	May 09 - 24	May 08 - 23
10	145 - 160	May 25 - 09 Jun	May 24 - 08 Jun
11	161 - 176	Jun 10 - 25	Jun 09 - 24
12	177 - 192	Jun 26 - 11 Jul	Jun 25 - 10 Jul
13	193 - 208	Jul 12 - 27	Jul 11 - 26
14	209 - 224	Jul 28 - 12 Aug	Jul 27 - 11 Aug
15	225 - 240	Aug 13 - 28	Aug 12 - 27
16	241 - 256	Aug 29 - 13 Sep	Aug 28 - 12 Sep
17	257 - 272	Sep 14 - 29	Sep 13 - 28
18	273 - 288	Sep 30 - 15 Oct	Sep 29 - 14 Oct
19	289 - 304	Oct 16 - 31	Oct 15 - 30
20	305 - 320	Nov 01 - 16	Oct 31 - 15 Nov
21	321 - 336	Nov 17 - 02 Dec	Nov 16 - 01 Dec
22	337 - 352	Dec 03 - 18	Dec 02 - 17
23	353 - 365+	Dec 19 - 03 Jan	Dec 18 - 02 Jan

Source: MODIS products information

NDVI has proved to have an extremely wide (and growing) range of applications. It is used to monitor vegetation conditions and therefore provide early warning on droughts and famines.

With the exception of very large irrigation schemes and commercial agriculture, an NDVI pixel very rarely covers a single homogeneous agricultural region. Instead it may cover roads, buildings, bare soil, small water bodies, natural vegetation and agriculture, all within one pixel. An NDVI pixel is the sum of the radiation reflected from all the land cover types within the area covered by the pixel. NDVI is an indicator of the condition of the overall vegetation in an area, including natural vegetation and agriculture.

Study objective:

The objective of this study was to investigate on recent drought in Mafraq area using the vegetation dynamics and NDVI -relationships.

Study area:

Mafraq governorate is located to the north-east of Amman capital of Jordan. The climate is characterized by dry hot summers and cold dry winters. The Mean Annual Maximum air temperature is 23.9 ºC and the Mean Annual Minimum air temperature is 9.3 ºC with an average total annual precipitation of 161.3 mm (Source: Jordan Climatological Handbook 2000 – Meteorological Department).

Agriculture especially irrigated farming using ground water forms the major land use in Mafraq Governorate (Table 1).

Table 1: Total land use and crop type in Mafraq Governorate.

Crop type	Agriculture system	Area (Dunum)
Vegetables		103160
Field crops		16440
Trees	Irrigated	51417
	Rainfed	4639
Citrus		10
Vine yards	Irrigated	7974
	Rainfed	2504
Olives	Irrigated	62586
	Rainfed	57151
Total		305881

Source: MOA statistics, 2009.

The study area is located between 32°25' - 32°08' N to 36°17' - 36°46' E (Figure 1). The crop map prepared by the crop mapping team was provided and used for detailed investigations.

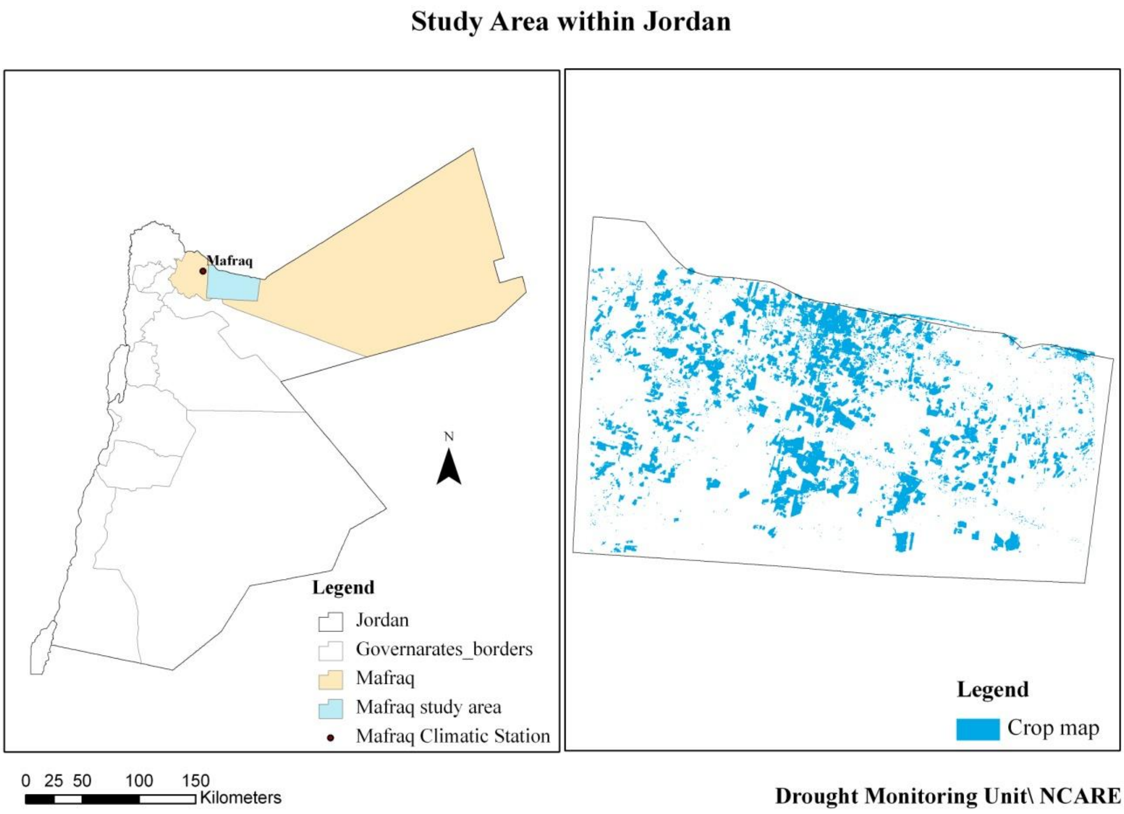


Figure 1: Study Area in Mafraq.

Satellite Data (MODIS):

The Time series of MODIS-NDVI 2000-2014, 16 day - MOD13Q1 data at 250-meter was used for this investigation, with the total of 334 images.

The images were downloaded from the NASA Website (https:// http://reverb.echo.nasa.gov/reverb/). Jordan is covered by two granules h21v05 and h21v06.

Metrological Data

Climatic data for Mafraq station was collected from the Jordan Meteorological Department.

Methodology and Analysis

Images Processing

The images were in standard HDF format. The layer of NDVI “composite of maximum value for every 16 day” were imported into image format (img) using the ERDAS Imagine software.

Image processing techniques included mosaic of the two granules of NDVI images to cover Jordan. The images were re-projected to the UTM standard projection using zone 36. A shapefile of study area was used to clip the produced images.

Models applied:

Different models were applied to process the data and derive maps of

- Mean and standard deviation NDVI value of the time series,
- Mean and standard deviation NDVI value for season 2013/2014,
- Mean NDVI value for every 16-day for the time series,
- The deviation of NDVI value for season 2013/2014 from the mean for the same period of the year for the time series 2000-2013,
- The difference between two consecutive images in season 2013/2014.
- The Vegetation condition index (VCI)

  The VCI is an indicator of the vigor of the vegetation cover as a function of NDVI minima and maxima for a given land are. It normalizes NDVI according to its average over many years and results in a consistent index for different land cover types (Vogt et al, 2000). It is an attempt to separate the short-term weather signal from the long-term signal, as reflected by the vegetation, making it a better indicator of water stress conditions than NDVI.

$$VCI = (NDVI - NDVImin)/(NDVImax - NDVImin)*100$$

The crop map:

According to the crop map received the main crops cultivated in the study area include: Olives, Fruit trees, Vine yards, Mixed mainly fruit trees, Barley, Tomatoe, Vegetables "April-July", Vegetables "April-August", potatoes, Vegetables "June-November", Vegetables "June-November", Vegetables "late harvest in December", Melon watermelon and zucchini (Figure 2).

The map indicated that the area planted by different crops vary from few hundreds to thousands square meters (Table 2).

In order to capture information from the NDVI images, it is necessary to use large area with same crop patterns covered within one pixel.

Crop map overlay on NDVI images

Overlaying the crop map on NDVI images was used to join information from both sources. The analysis involved two approaches:

1. Grouping crop types into three groups: trees, field crops and vegetables (Figure 2).

2. Selecting areas covered by similar group type with minimum area more or equal to 50000 meter square. This resembles at least 90% coverage of same group in one pixel of 250 m.
    - Pixels that match the above characteristics were used as Area of interest "AOI" and these pixels were converted into ASCII files for further statistical analysis.
    - The mean of these sampled pixels were used in NDVI growth profile analysis of different groups.
    - Detailed information about each group, areas, and number of pixels analyzed can be found in table 2 (Figure 3).

Table 2: Detailed information about crop type areas and grouping, and sampled pixels

	Grid code	Crop type	Maximum area	Minimum area	Mean area	Total area	Total pixel area	Selected pixel area	No. of sample pixels
			Meter Square						
Group 1	10	Olives	2243686.3	463.4	12460.9	31438961.3			
	20	Fruit trees	1617942.9	576.8	22402.5	23970646.1			
	30	Vine yards	92847.2	577.0	8362.7	953346.0			
	150	Mixed mainly fruit trees	259566.3	322.3	2712.0	18175789.8			
	Total area					74538743.2	91134226.8	688219.5	151
Group 2	51	Barley	3220728.2	51.2	9304.1	45432037.7	43216950.4	309242.5	59
Group 3	60	Tomatoe	261022.8	576.8	12261.9	11661096.5			
	61	Vegetables "April-July"	76077.1	576.8	2042.2	2344487.2			
	62	Vegetables "April-August"	38303.7	576.9	2380.9	249991.1			
	63	Potatoes	66334.6	900.8	26698.8	106795.4			
	65	Vegetables "June-November"	210741.3	576.8	7331.2	15520231.0			
	66	Vegetables "June-November"	220163.7	576.8	2771.8	15350484.5			
	68	Vegetables "late harvest in December"	200801.4	0.7	3254.5	7830282.0			
	70	Melon watermelon and zucchini	70593.6	576.9	6793.3	889919.0			
	Total area					53953286.7	106111293.9	82938.4	16

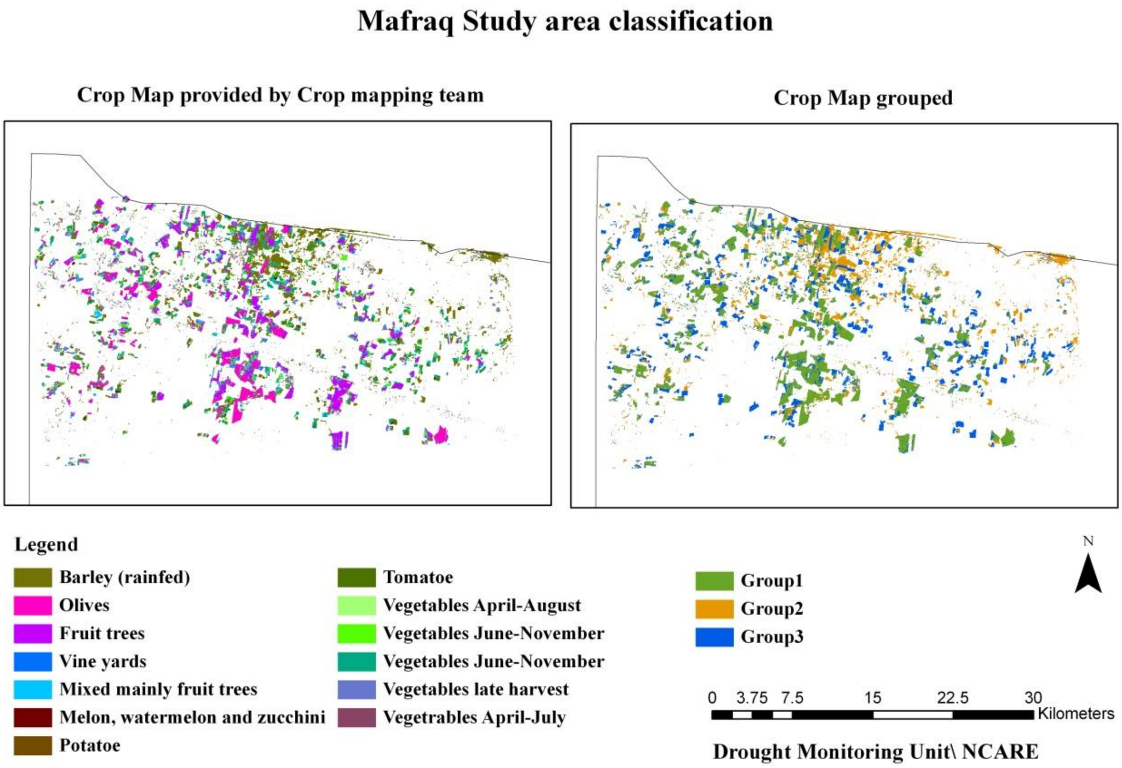


Figure 2: Crop map grouped into 3 groups

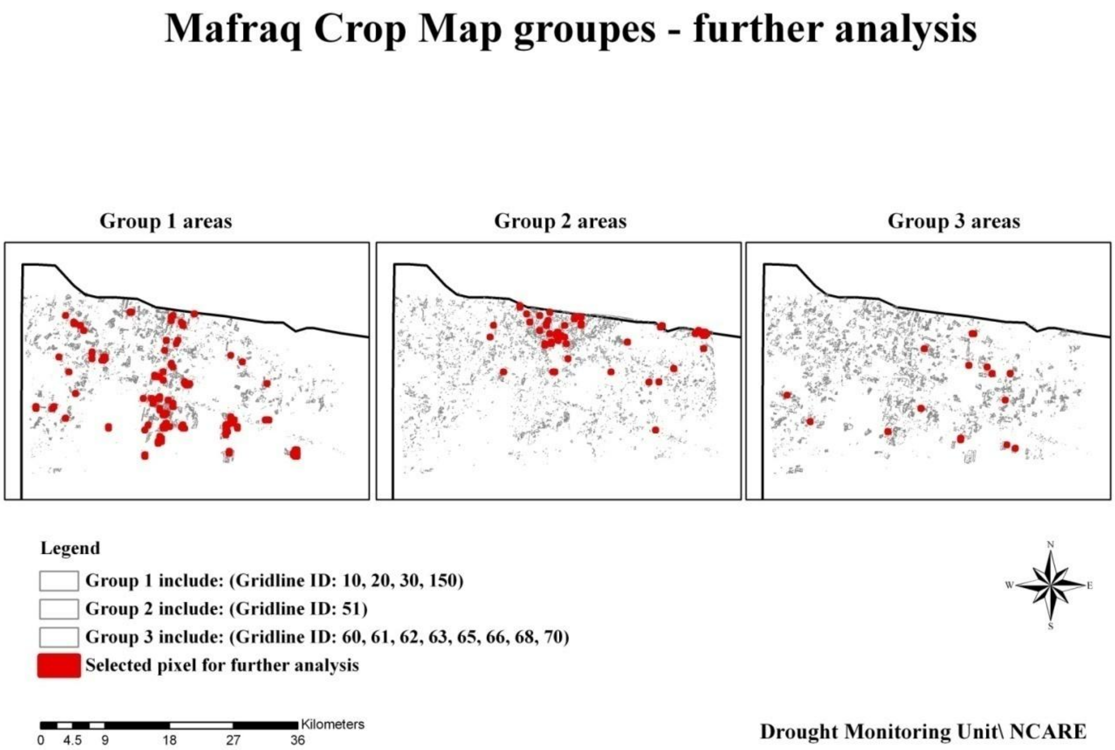


Figure 3: Group maps and pixels used for further analysis.

Results and Discussion:

General analysis of study area:

The long term statistical NDVI maps (Figure 4) show that the study area is characterized by low to medium vegetation (NDVI less than 0.4). The tree areas (group1) show the highest NDVI values.

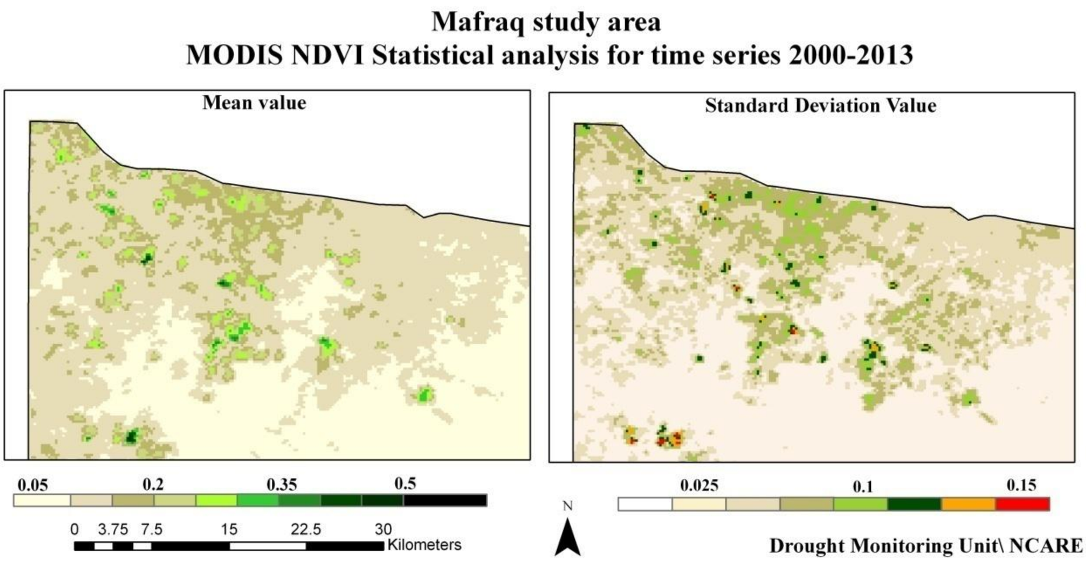


Figure 4: MODIS NDVI Statistical analysis for time series 2000 -2003.

The mean standard deviation ranges from 0.025 in open rangeland areas up to more than 0.1 in cultivated areas.

Long term seasonal growth pattern:

The long term seasonal growth pattern was studied using the mean 16-day image for the time series 2000-2013. The output images (Figure 5) show relatively high NDVI values in different areas and in different periods:

- High values of NDVI that occur during the period from "May to November" signify the summer irrigated trees and vegetables.
- The change in NDVI pattern during the period from "December to April" indicate the rainfed agriculture.
- The continuous relatively high NDVI values >0.2 are presumed to indicate the areas cultivated with olive trees (permanent vegetation).

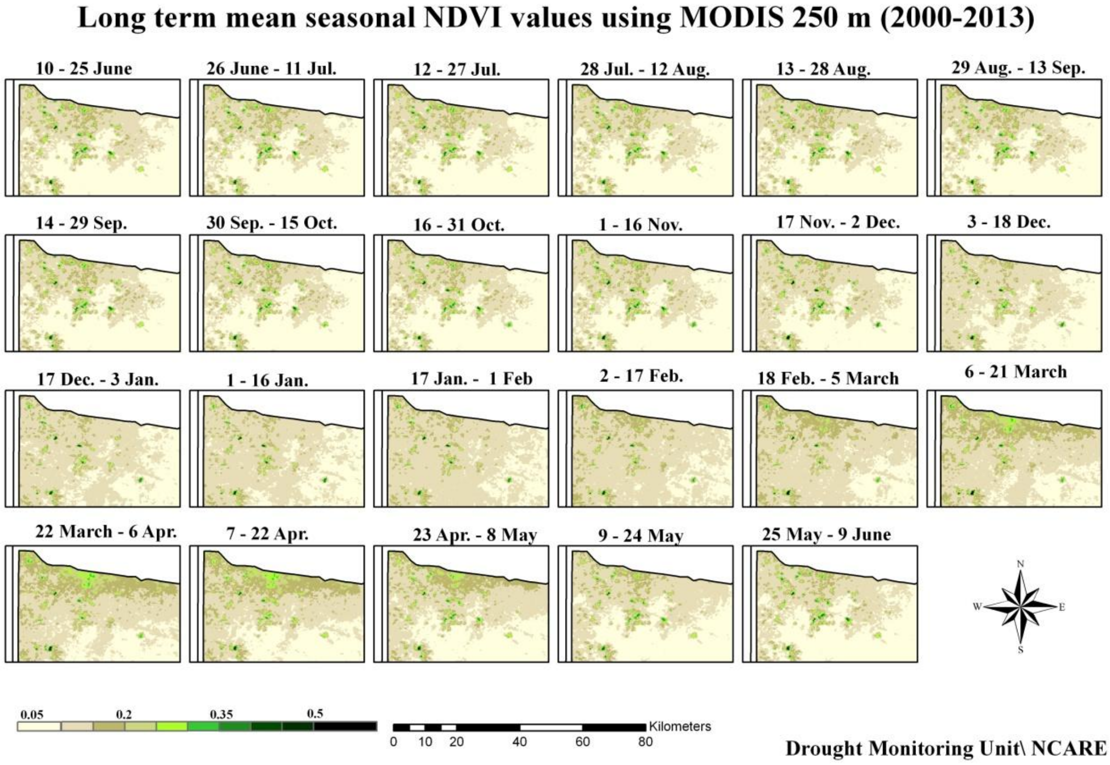


Figure 5: MODIS NDVI long term seasonal growth for time series 2000 -2013.

Analysis of Season 2013/2014:

The season 2013/2014 maps (Figure 6) show that the study area had better vegetation value in most of the cultivated areas in comparison with the long term mean.

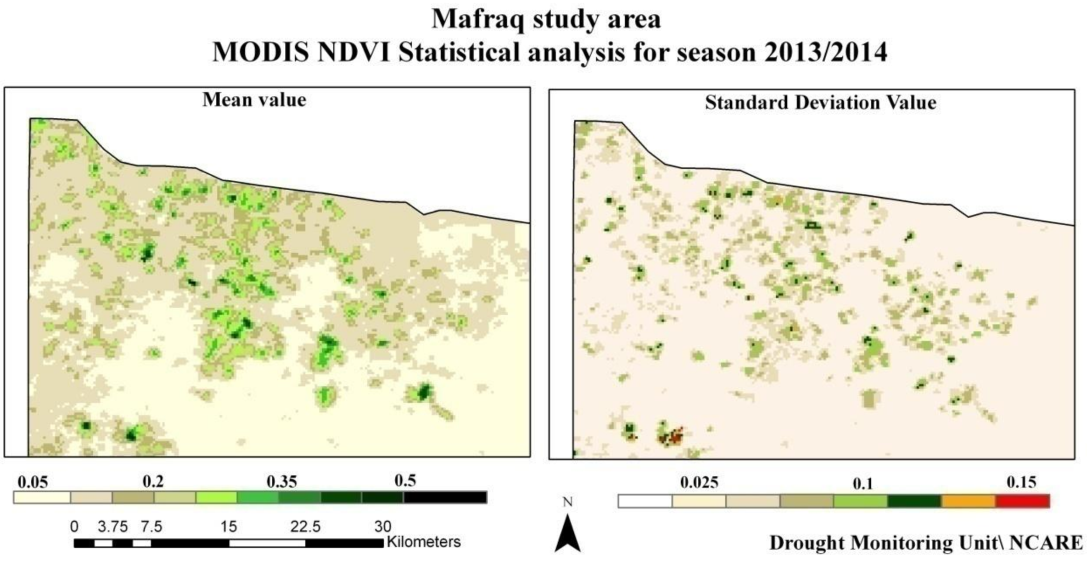


Figure 6: MODIS NDVI statistical analysis for season 2013/2014.

The season 2013/2014 mean standard deviation values greater than 0.075 distinguish the areas of cultivation activities during the season.

Season 2013/2014 mean deviation from long record:

The deviation of season 2013/2014 NDVI values from the long term mean NDVI values (Figure 7) show that most of the cultivated areas had better NDVI values than the long term mean.

The use of a mask formed from the crop map show that most of the green color (above the mean values) are found in the cultivated areas. Whereas, the orange and red color (below the mean values) are found in open rangelands.

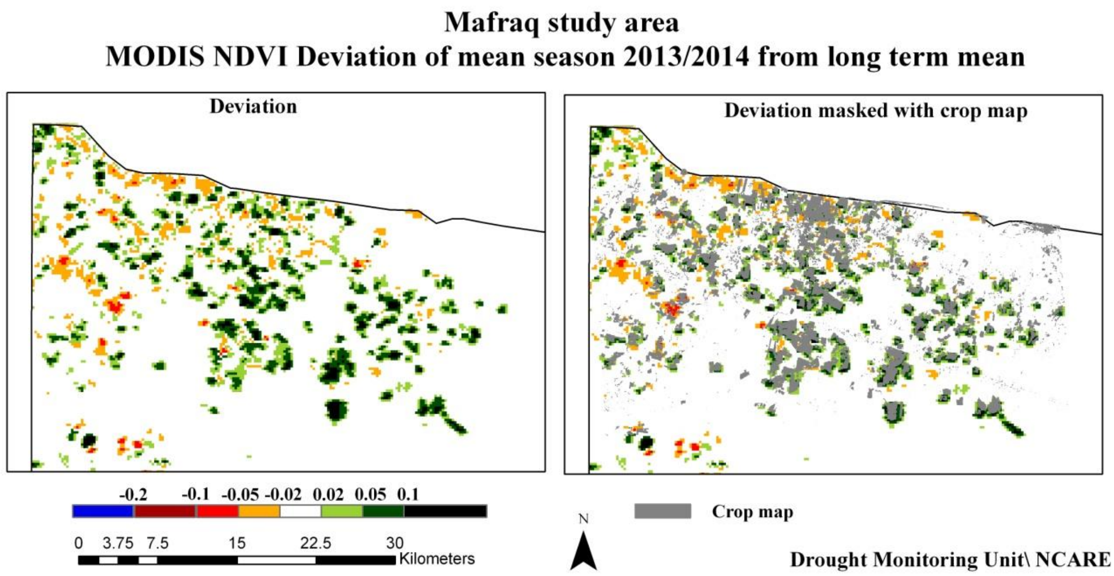


Figure 7: MODIS NDVI Deviation of mean season 2013 from long term mean.

Season 2013/2014 growth pattern:

Studying the mean 16-day maps for season 2013/2014 (Figure 8) again distinguish between different growing patterns in the study area (summer, permanent and rainfed season).

- High values of NDVI values from "May to November" show the summer irrigated trees and vegetables during the season 2013/2014.
- The change in NDVI pattern during the period from "December to April" indicate the pattern of rainfed agriculture during the season 2013/2014.
- The continuous relatively high NDVI values >0.2 are presumed to indicate the areas cultivated with olive trees (permanent vegetation).

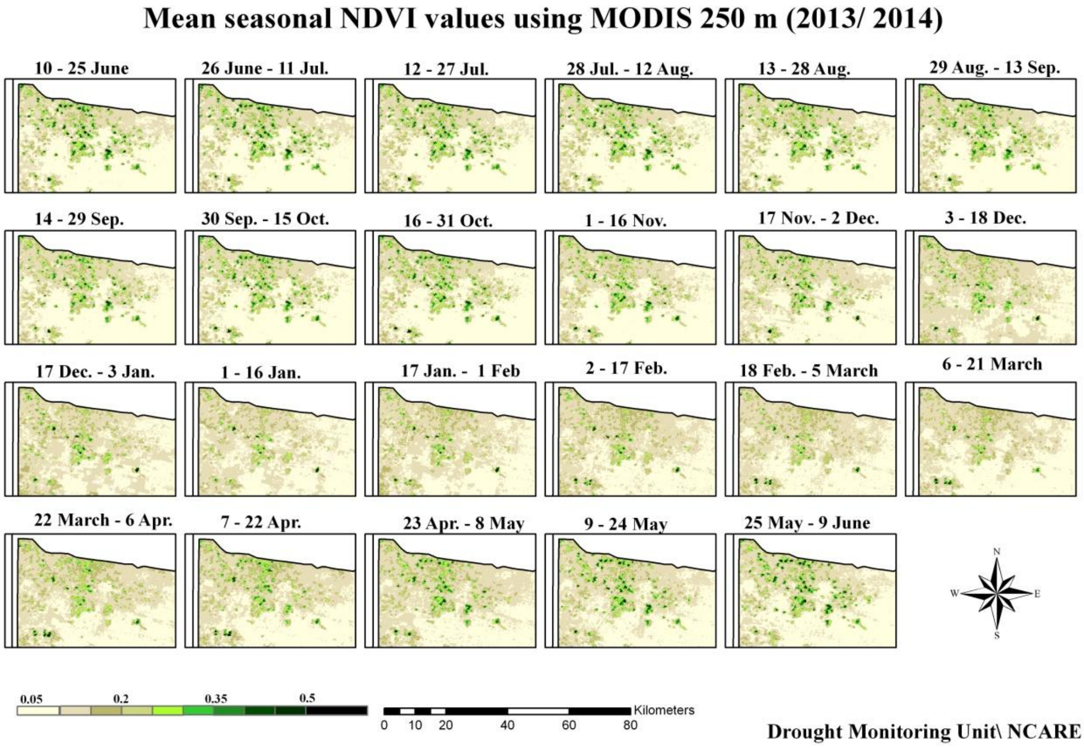


Figure 8: MODIS NDVI seasonal 2013/2014 growth pattern.

Crop Groups growth pattern:

The data extracted from the ASCII files related for each of the three groups were used to calculate mean values of all pixels in order to understand the growth pattern of each group both for the long term and season 2013/2014 (Figure 9).

Generally the profiles show that the NDVI values of season 2013/2014 had higher values but nearly parallel values to that of the long term profiles. In general, the following can be noticed for each group:-

- Group 1 (trees) has the highest NDVI values with no peak growth with highest variation during the period between November and March.
- Group 2 has growth pattern of peak value during Spring. Variation goes along with the growth pattern. Nevertheless, high values in summer could indicate that the land is used for summer cultivation as well. Unless the pixels used for analysis have mixed land use (barley and irrigated summer crops).
- Group 3 has the lowest NDVI values with no obvious peak. Variation again is highest during period from November and March

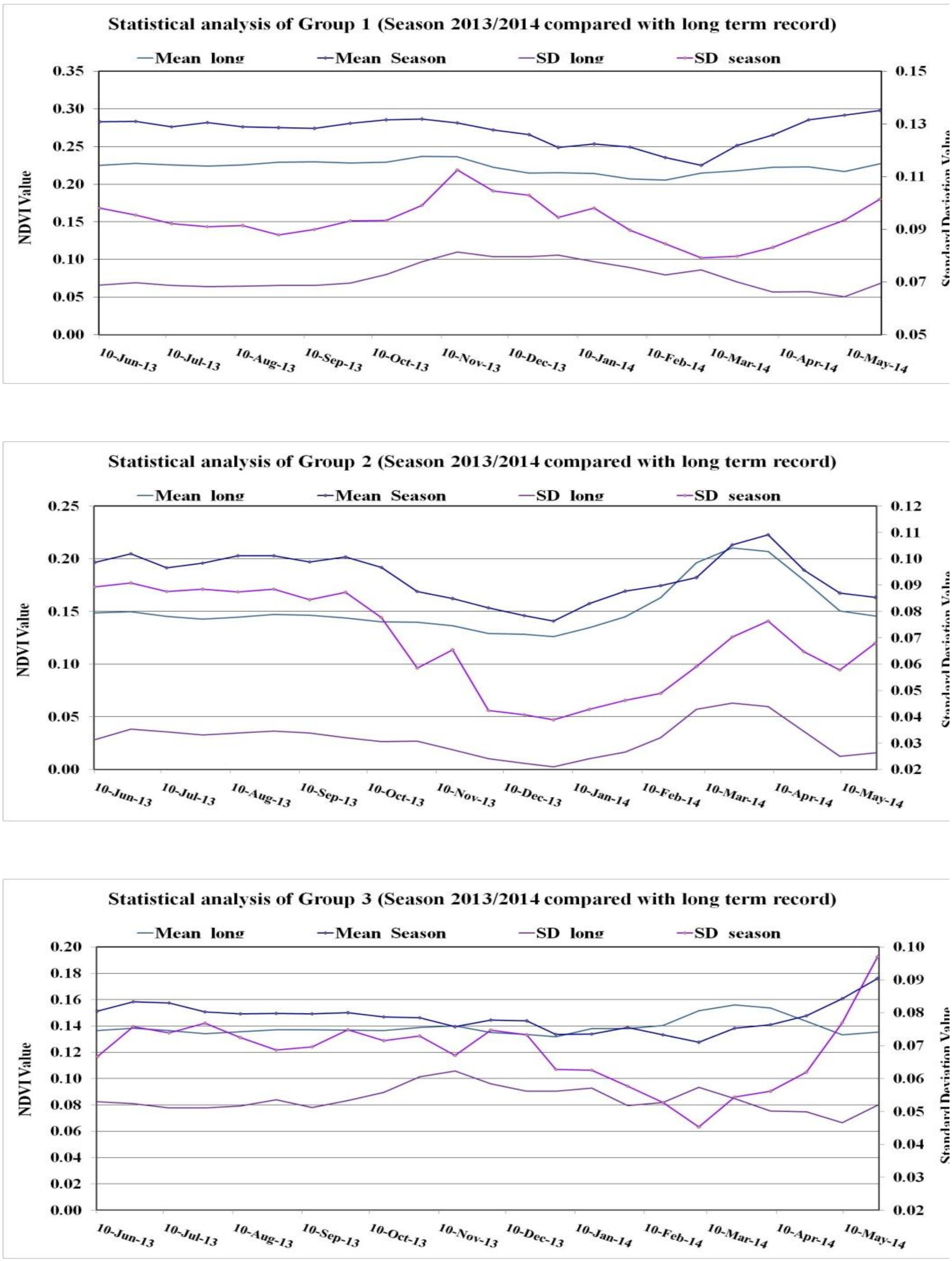


Figure 9: Mean MODIS NDVI values growth profiles for the three groups in study area (long term and season 2013/2014).

Season 2013/2014 deviation from the mean long record pattern:

Analyses of the season 2013/2014 growth pattern deviation from the mean show the periods were vegetation growth was above or below average (Figure 10).

- During summer period irrigated areas clearly have deviation values above the mean.
- During the rainy season the deviation was below average (especially in rainfed areas) affected by rainfall shortages during the period from January to March (Figure 11).

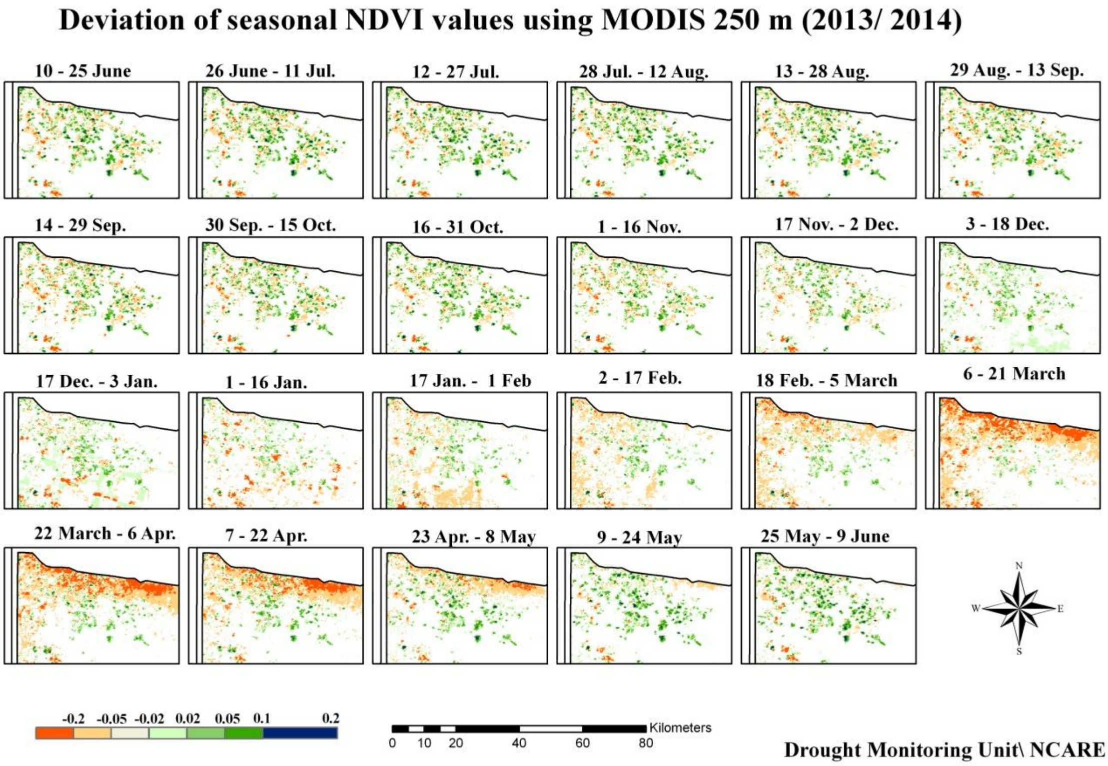


Figure 10: MODIS NDVI Season 2013/2014 Deviation from the mean.

Rainfall pattern for season 2013/2014:

The season 2013/2014 had a good pattern in the beginning of the season, but it was broken by a long period of rainfall shortages during the period from January to March.

Heavy amounts of rainfall were received in the second week of March, where the drought effect was minimized.

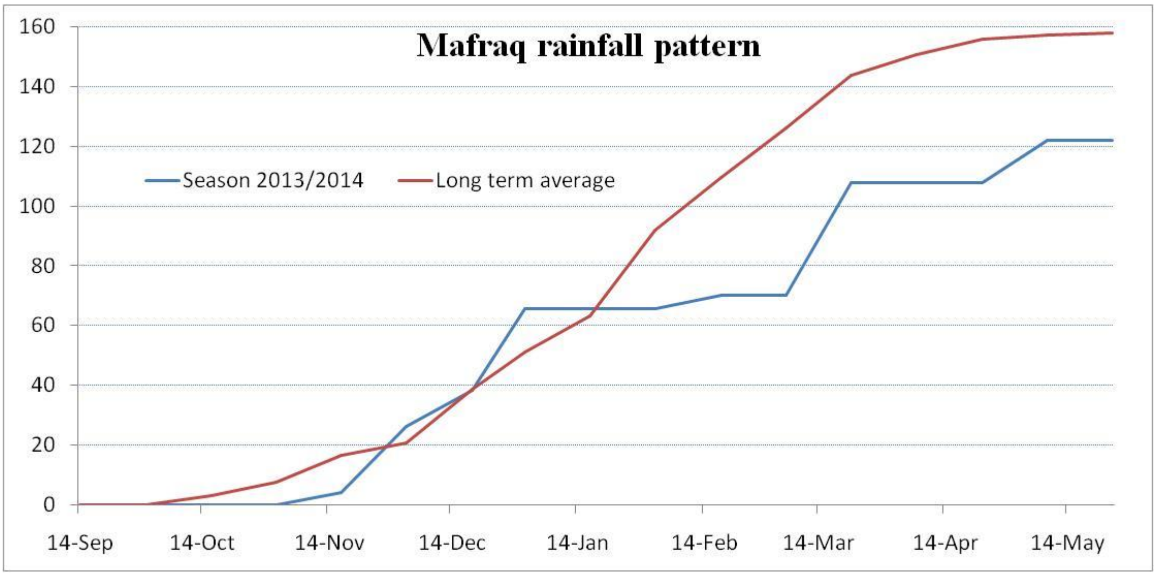


Figure 11: Rainfall pattern in Mafraq for season 2013/2014 compared with the long average.

Crop Groups NDVI deviation from the mean pattern:

The three group's deviation from the mean show that the NDVI values were above the mean (0.02-0.08 of NDVI value) most of the season except during the period from January to March, where the NDVI values were below average due to the rainfall shortages (Figure 12).

Heavy rainfall received in the second week of March reduced the drought impact in the following dates for the three group types.

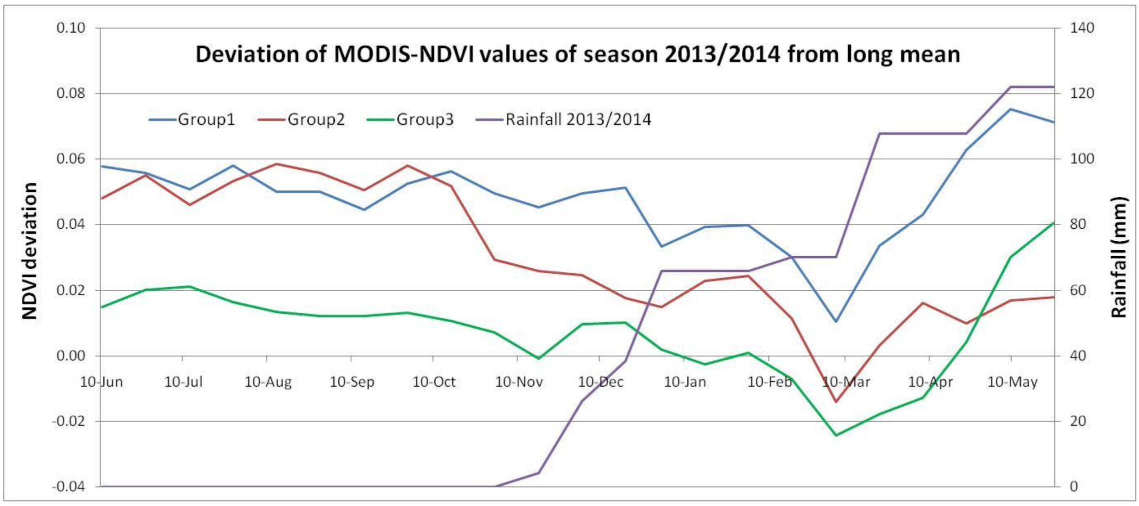
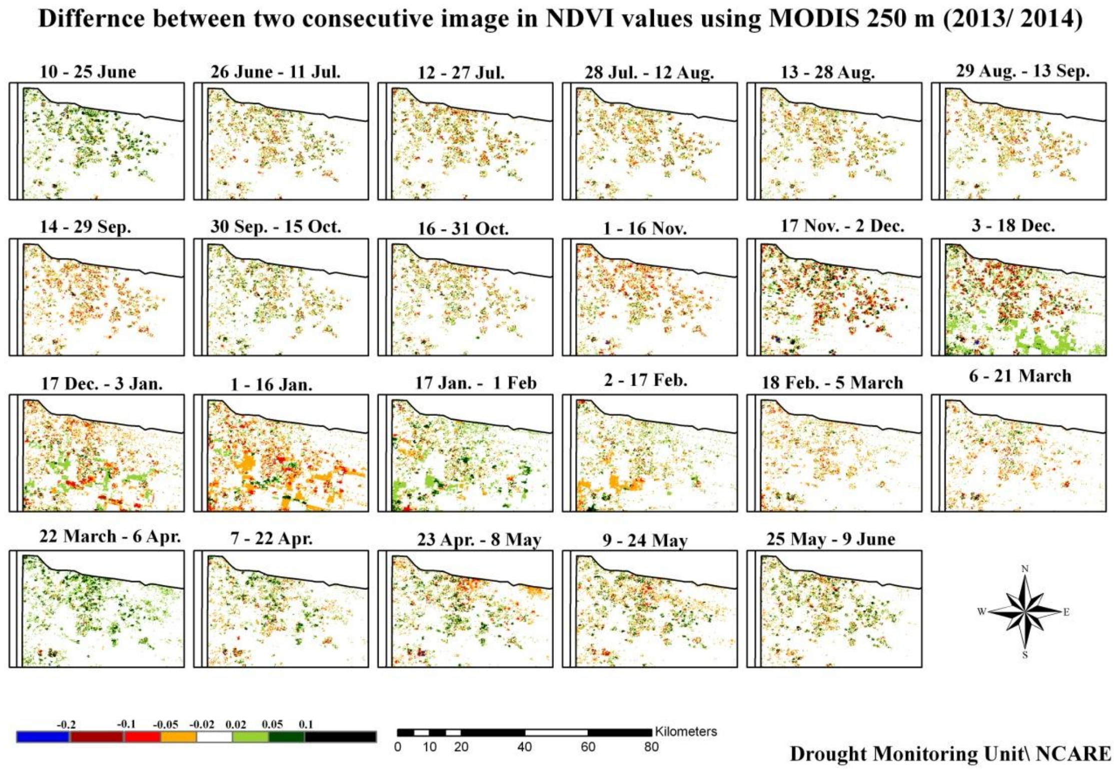


Figure 12: Profiles MODIS NDVI deviation from the mean values for Season 2013/2014

Season 2013/2014 difference between two consecutive images:

The importance of using this index comes from the need to understand the continuity of vegetation growth (Figure 13), the difference maps show the following:

- Variation of the vegetation cover (plus and minus) during the period from "May to November" could be attributed to irrigation scheduling and agricultural practices,
- The change in vegetation during December is related with the low temperature and snow that affected the country in the second week of December.
- The high rainfall (snow) amount that came in December had good impact on increasing vegetation during the second half of January.
- Heavy rainfall received in the second week of March impact is obvious in increasing the NDVI values during the following period of March 22 to April 6th.



-

Figure 13: MODIS NDVI Season 2013/2014 Difference between two consecutive images.

Season 2013/2014 Vegetation Condition Index (VCI):

The VCI values range from 0 to 100. Low values of VCI indicate stress or poor vegetation condition, possibly related to the impact of drought, whereas high values would suggest the good vegetation condition.

The season VCI maps (Figure 14) show low VCI values in most of the study area, all over the season indicating drought conditions. More drought conditions are obvious during the period from February to April.

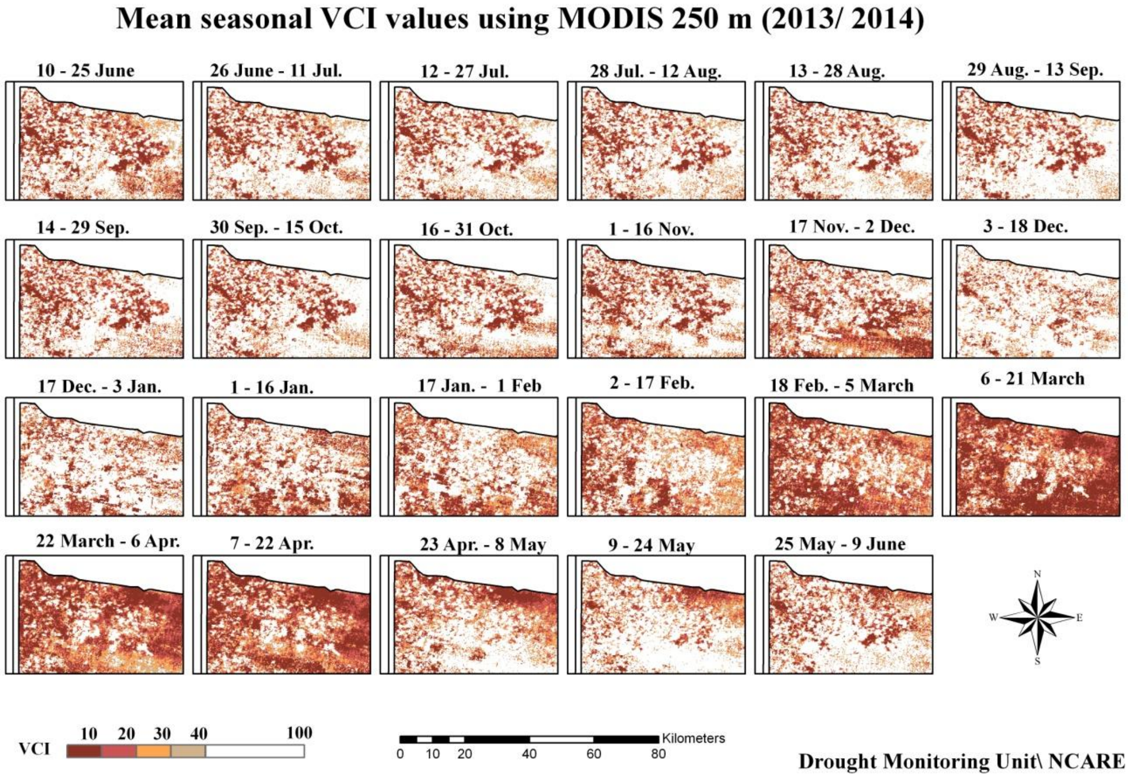


Figure 14: MODIS NDVI calculated VCI values for season 2013/2014

Detailed investigation of the maps and the use of a mask of the crop map (Figure 15 and 16) show that most of the low values < 30 are in the uncultivated "rangeland areas" indicating drought conditions. Meanwhile the cultivated/ irrigated areas were not affected by drought (VCI values > 40).

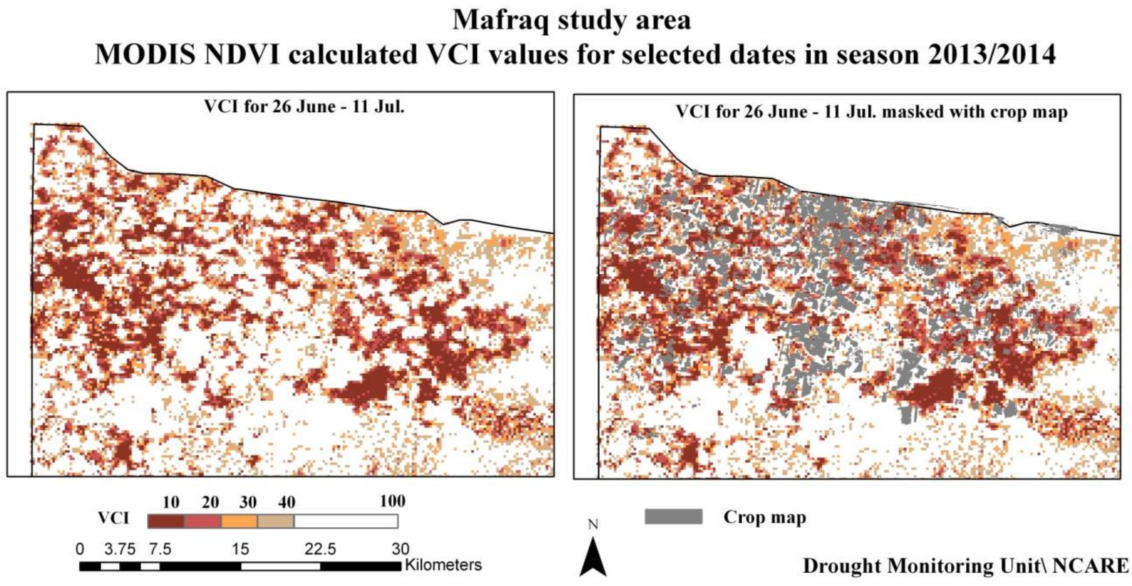


Figure 15: MODIS NDVI calculated VCI values for the period 26 June – 10 July with and without crop map mask.

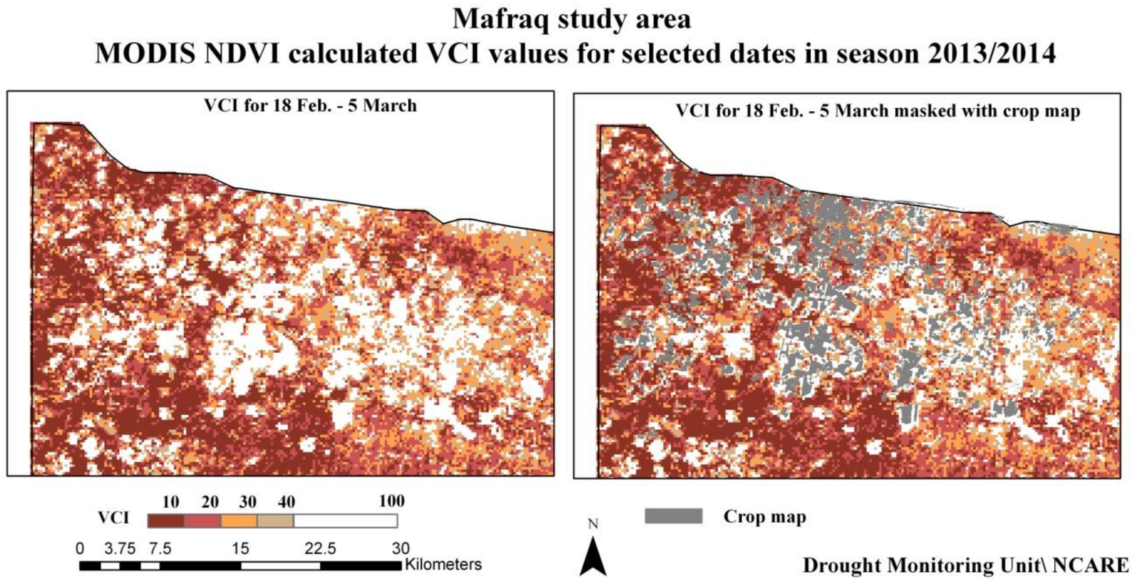


Figure 16: MODIS NDVI calculated VCI values for the period 18 February – 5th March with and without crop map mask.

Crop Groups VCI pattern:

The three group's VCI patterns (Figure 17) show that cultivated areas were not affected by drought (VCI > 40) most of the season. VCI lowest values are found in early Spring due to rainfall shortages.

Several pixels (15) representing the uncultivated rangeland were sampled to compare the VCI values of cultivated versus the non-cultivated area. The average of these pixels shows that the open rangeland areas are under severe drought conditions <10. The drought conditions were decreased during the period November to February following the rainfall periods.

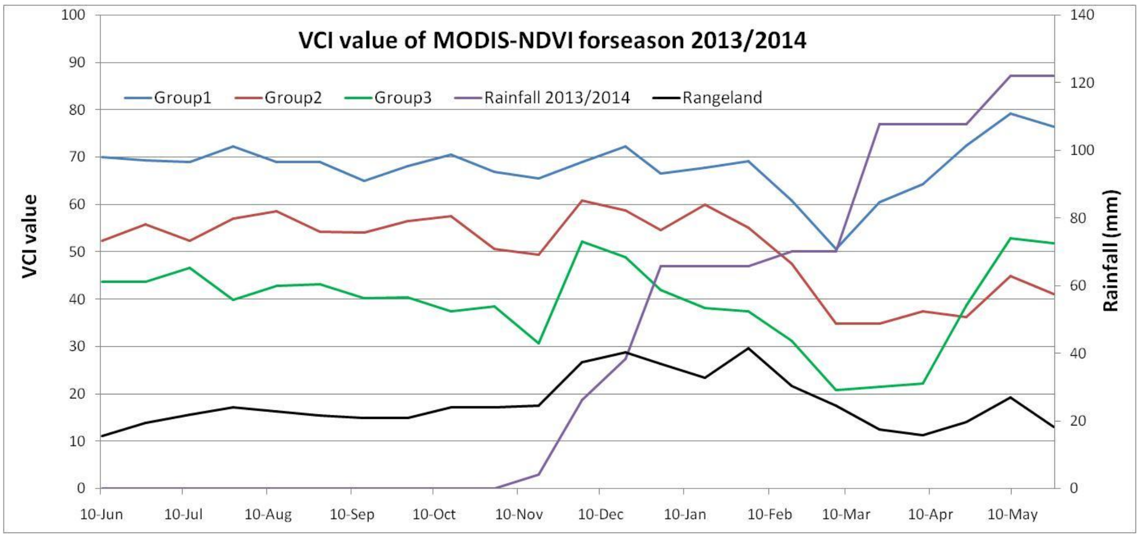


Figure 17: MODIS NDVI calculated VCI profiles for Season 2013/2014

Summary and conclusions

MODIS NDVI values and models used to analyze the vegetation growth and drought condition have provided a comprehensive picture of the crops cultivated in the study area.

- The long term NDVI seasonal growth pattern for different crop groups can help in distinguishing between the different crops.
- The persistence of high NDVI values during the summer season indicate that most of these areas are under irrigation.
- Shortages of rainfall during the period from January to March were reflected in the different indices and growth profiles, especially in rainfed agriculture and rangeland.

Interpretation of the various NDVI patterns and models must be followed up by fieldwork to establish the actual conditions on grounds.

References:

1. Al-Bakri, J. T., and Taylor, J. C., 2003. Application of NOAA AVHRR for monitoring vegetation conditions and biomass in Jordan. Journal of Arid Environments, 54, 579–593.
2. Al-Bakri, J. T., Taylor, J. C., and Brewer, T.R., 2001. Monitoring land use change in the badia transition zone in Jordan using aerial photography and satellite imagery. The Geographical Journal, 167 (3) 248–262.
3. Al-Naber, G., J. Al-Bakri and M. Saba, (2009). "Monitoring Drought and Desertification in Jordan with Remote Sensing". Proceedings of The Remote Sensing and GIS Symposium, 20 April 2009, Geography Department/ Faculty of Arts - University of Jordan , pp 53-61.
4. Anyamba, A., and Tucker, C.J., 2005. Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003. Journal of Arid Environments, 63, 596–614.
5. Bai, Z. G., Dent D. L., Schaepman, M. E., 2005. Quantitative Global Assessment of Land Degradation and Improvement: pilot study in North China. Waeningen University Report, 2005/2006.
6. Bajgiran, P. R., Darvishsefat A. A., Khalili, A., Makhdoum, M. F., 2007. Using AVHRR-based vegetation indices for drought monitoring in the Northwest of Iran. Journal of Arid Environments, 72, 1086–1096.
7. Chandrasekar K., Sesha Sai, M. V. R., Jeyaseelan, A. T., Dwivedi, R. S., Roy, P. S., 2006. Vegetation response to rainfall as monitored by NOAA–AVHRR. Current Science, 91 (12), 1626-1633.
8. Chen, X., Tan, Z., Schwartz, M. D., Xu, C., 2000. Determining the growing season of land vegetation on the basis of plant phenology and satellite data in Northern China. Int. J. Biometeorol., 44, 97–101.
9. Jordan Climatological Handbook 2000 – Meteorological Department
10. Karlsen, S. R., Tolvanen, A., Kubin, E., Poikolainen, J., Høgda, K. A., Johansen, B., Danks, F. S., Aspholm, P., Wielgolaski, F. E., Makarova, O., 2008 MODIS-NDVI-based mapping of the length of the growing season in northern Fennoscandia. International Journal of Applied Earth Observation and Geoinformation, 10, 253–266
11. Rahimzadeh Bajgiran, P., Darvishsefat, A. A., Khalili, A., Makhdoum, M. F., 2008. Using AVHRR-based vegetation indices for drought monitoring in the northwest of Iran. Journal of Arid Environments 72, 1086–1096.
12. Saba, M., G. Al Naber, Y. Mohawesh (2010) "Analysis of Jordan Vegetation Cover Dynamics Using MODIS-NDVI from 2000-2009. Presented at the International Conference on Food Security and Climate change, in February 2010, organized by ICARDA and NCARE
13. Salim, H. A., Chen, X., Gong, J., 2007. Analysis of Sudan Vegetation Dynamics-Using NOAA-AVHRR NDVI Data from 1993-2003.Online Journal of Earth Sciences, 1(4), 163-169.
14. Schmidt, H., and Karnieli A., 2000, Remote sensing of the seasonal variability of vegetation in a semi-arid environment. Journal of Arid Environments. 45, 43–59.

15. Senay, G.B., Elliott, R.L., 2000. Combining AVHRR-NDVI and landuse data to describe temporal and spatial dynamics of vegetation. Forest Ecology and Management, 128, 83-91.

16. Shutova, E., Wielgolaski, F. E., Karlsen, S. R., & Makarova, O., Berlina, N., Filimonova, T. , Haraldsson, E., Aspholm, P. E., Flø, L., Høgda, K. A., 2006. Growing seasons of Nordic mountain birch in northernmost Europe as indicated by long-term field studies and analyses of satellite images. Int. J. Biometeorol., 51:155–166.

17. Stow, D. A., Hope, A., McGuire, D., Verbyla, D., Gamon, J., Huemmrich, F., Houston, S., Racine, C., Sturm, M., Tape, K., Hinzman, L.,Yoshikawa, K., Tweedie, C., Noyle, B., Silapaswan, C., Douglas, D., Griffith, B., Jia, G., Epstein, H., Walker, D., Daeschner, S., Petersen, A., Zhou, L., Myneni, R., 2004. Remote sensing of vegetation and land-cover change in Arctic Tundra Ecosystems. Remote Sensing of Environment, 89, 281–308.

18. Vogt, J.V., S. Niemeyer., F. Somma., I. Beaudin., and V.V. Viau. 2000: Drought monitoring from space. Chapter in: Drought and Drought Mitigation in Europe, eds. Vogt, J.V., and F. Somma. Kluwers Publ.

19. Wardlow, B. D., Egbert, S. L., 2008. Large-area crop mapping using time-series MODIS 250 m NDVI data: An assessment for the U.S. Central Great Plains. Remote Sensing of Environment, 112, 1096–1116.

20. Wardlow, B. D., Egbert, S., L., Kastens, J. H., 2007. Analysis of time-series MODIS 250 m vegetation index data for crop classification in the U.S. Central Great Plains. Remote Sensing of Environment, 108, 290–310

21. Weiss, J. L., Gutzler, D. S., Allred Coonrod, J. E., Dahm, C. N., 2004. Long-term vegetation monitoring with NDVI in a diverse semi-arid setting, central New Mexico, USA. Journal of Arid Environments. 58, 249–272.

22. Yu, F., Price, K. P., Ellis, J. Shi, P., 2003 Response of seasonal vegetation development to climatic variations in eastern central Asia. Remote Sensing of Environment, 87, 42–54.

23. Zhang, X., Friedl, M. A., Schaaf, C. B., Strahler, A. H.,. Hodges, J. C.F, Gao, F., Reed, B. C., Huete, A., 2003. Monitoring vegetation phenology using MODIS Remote Sensing of Environment, 84, 471–475.

24. Zhang, X., Friedl, M.A., Schaaf, C. B., 2006. Global vegetation phenology from Moderate Resolution Imaging Spectroradiometer (MODIS): Evaluation of global patterns and comparison with in situ measurements. Journal Of Geophysical Research, 111, 1-14.