A study using multitemporal Sentinel-2 data and Digital Elevation Model for calculating morphometric parameters over the Euphrates River Basin in Syria

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Abstract

The Euphrates River, the longest river in Western Asia, is the main river running in three riparian countries, Turkey, Syria, and Iraq. This research focuses on the Syrian part of the basin which makes 22% of total area of the basin. Analyzing and evaluating the morphometric parameters may help to understand the nature of surface and can be useful also for the sustainable territorial planning and management. The goal of this study is to the usability of the Sentinel-2 satellite images for determining the land use/land cover categories and to calculate certain morphometric parameters derived from Digital Elevation Model. Different morphometric characteristics have been generated in GIS environment and Sentinel-2 remote sensing data have been processed and analyzed using geospational techniques. The results allow the automated segmentation of the terrain based on derivatives of the input data. This division is compared to the typical land cover/land use of the various governorates in Syria.As our study area is a long-lasting military conflict zone, this study will also help to better evaluate the river basin in Syria and to understand some practical problems related to the environment including soil conservation and water conservation in term of irrigation land and drinking water supply which would also be affected by the armed conflict there.

Introduction

The Euphrates River is the longest river in western Asia, which flows through Turkey, Syria and Iraq to join the Tigris river in the Shatt al-Arab which empties into the Persian Gulf (Fig. 1). In Syria the Euphrates River basin covers 51238 km^2 (28% of the country's surface area) with a total length of 610 km and an average discharge of 583 m^3/s.

According to the Syrian division of the hydrological basins, the Euphrates river is considered as a part of the Euphrates and Aleppo rivers basin including (Al Quick river) on the west (155 km) and the basin contains also the tributary river of (Al Blikh river,166 km) and the tributary river of (Al Sajoor) with 27km length in Syria.

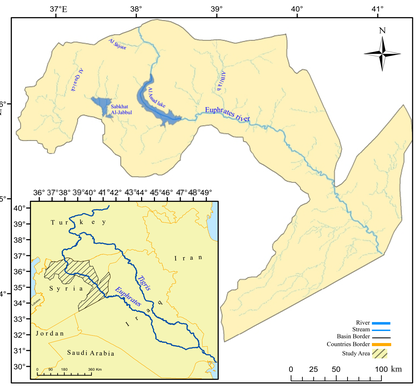

Fig. 1.Euphrates and Aleppo Rivers Basin in Syria

Data and Methodology

The remote sensing data in combination with different GIS and cartographic techniques are the used tools in this research.

The digital elevation model is the SRTM3 (Shuttle Radar Topography Mission 3 arcsec) data reprojected to UTM Zone 37N that has been used to extract various derivatives and to calculate morpho-metric attributes. The elevation within the study area is ranging from 133 m to 807 m a.s.l. (Fig.2)

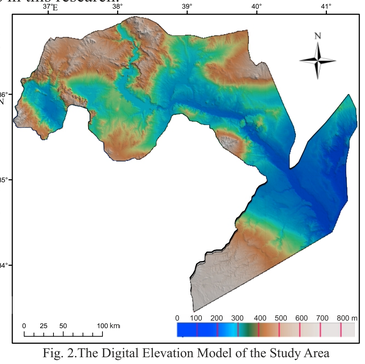

Fig. 2.The Digital Elevation Model of the Study Area

Both Sentinel-2A satellite imagery with Landsat-5 TM data were used for the analysis after being radio-metrically corrected and the Sentinel-2A data were resampled to 30-meter resolution (Fig. 3)

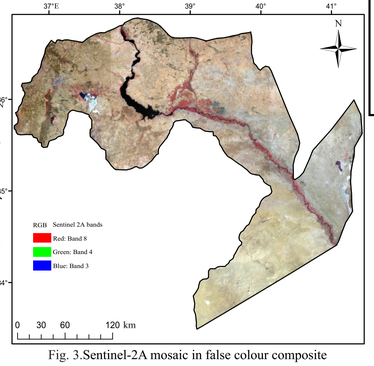

Fig. 3.Sentinel-2A mosaic in false colour composite

After the calculation of Normalized Difference Vegetation Index (NDVI) the results were reclassified to five categories (Table 1).

Class	NDVI values
Water bodies	from -1 to 0.015
Bare and built-up areas	from 0.015 to 0.1
Shrub lands	from 0.1 to 0.4
Crop fields	from 0.4 to 0.6
Dense vegetation	from 0.6 to 1

Table 1. NDVI categories

Almost 81% of the basin area is located within three governorates (Aleppo, Ar-Raqqa, Deir-ez-Zor). (Fig. 4) summarizes the distribution of the land use in 2017 based on governmental annual statistics. For Ar-Raqqa and Deir-ez-Zor governorates meadows and pastures are forming the majority of the land use, whereas the arable land is the main type of land use in the governorate Aleppo.
Non-arable land (barren surfaces, urban areas, rivers, water bodies) ratio is significant in Deir-ez-Zor governorate and partly in Aleppo governorate.

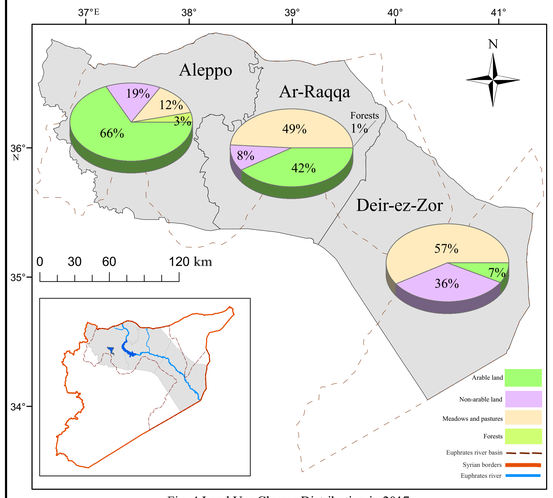

Fig. 4.Land Use Classes Distribution in 2017

Stream Power Index (SPI) is very useful for ravine identification within the study area and also highlights the areas with potential erosion.
After calculating threshold percentile values we found that the area with high potential erosion make up 13.5% of the total area.
The SPI map is showing threshold percentile values for different areas within the basin and the dark areas with high erosion intensity (Fig. 5).

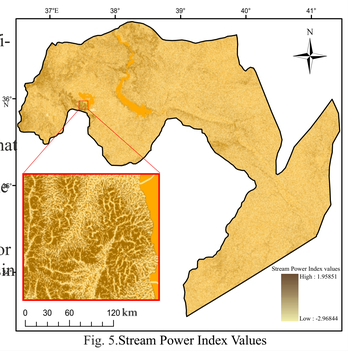

Fig. 5.Stream Power Index Values

The satellite images data are chosen in the same period of each year 2003,2011 and 2019 in the middle of (July) to have a better view of the surface with a clear sky and as summer progresses and the landscape dries out, bare soil would be distinguished.

Image Acquisition period	Sensor	Bands	Resolution
Mid -July 2003	Landsat 5 TM	1,2,3,4,5	30m
Mid -July 2011	Landsat 5 TM	1,2,3,4,5	30m
Mid -July 2019	Sentinel -2A	1,2,3,4, 8	30m

In order to understand the relationship between NDVI values and terrain attributes the results are visualized using scatter plots, allowing the visual analysis of the relationship of these variables. (See above.)

86% of the total slopes in the basin is considered as mixed between flat and gently undulating landform as the dominant slopes are ranging in 0°-5° within the study area (Fig. 6).

No correlation between the NDVI and the first order derivatives of the DTM (slope, aspect) can be detected (Figs. 7 and 9).

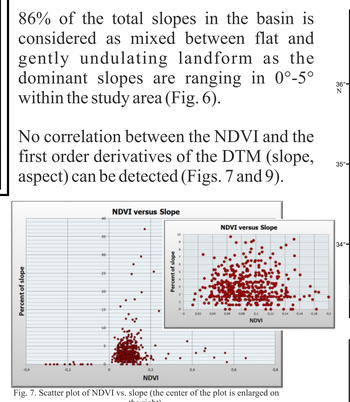

Fig. 7. Scatter plot of NDVI vs. slope (the center of the plot is enlarged on the right).

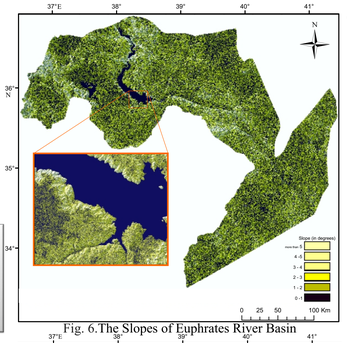

Fig. 6.The Slopes of Euphrates River Basin

Compound Topographic Index (CTI) is very useful to identify potential locations for ephemeral gullies and is strongly correlated with soil moisture and it is representing in the map as places with large catchments.

In (Fig. 10) we can see the details of Al Assad lake and Sabkhat al-Jabbul which is a large saline lake and we can identify also where are the critical sites with high soil erosion which create sediments and effect water management in the study area.

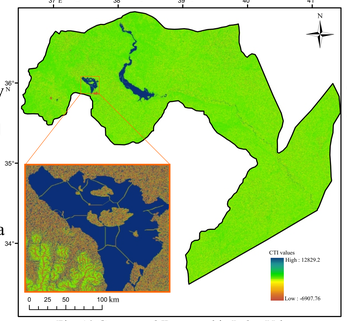

Fig. 10.Compound Topographic Index Values

Results

The Aspects (direction of the slope) calculated using DEM (Fig. 8).

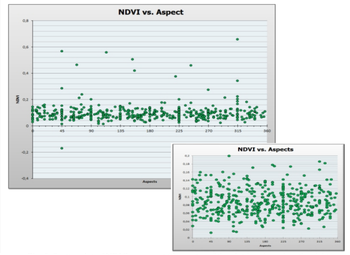

Fig. 9. Scatter plot of NDVI vs. aspect (the center of the plot is enlarged on the right corner).

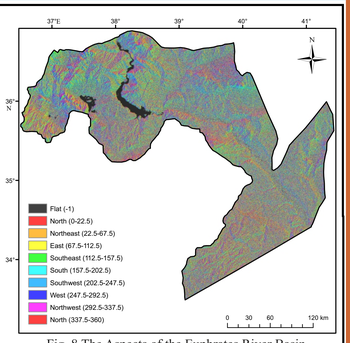

Fig. 8.The Aspects of the Euphrates River Basin

There is no correlation between NDVI and CTI and that is mainly because of the detection time which would be higher in growing season or in winter due to moisture availability (Fig. 11).

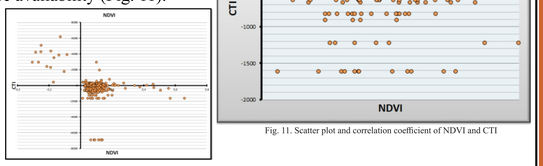

Fig. 11. Scatter plot and correlation coefficient of NDVI and CTI

After calculating NDVI values for each year, the results have classified into five land cover categories: water bodies, Bare surface (including built up areas), shrub and grassy land and forest.
The following table and figures show the classification results and we can see the negative change for both shrub and grassland class and the forest as the green cover (last three categories) is gradually decreased from 314733 hectares in 2003 to 228634 hectares in 2019 by losing area for the first two classes.

Class	2003	2011	2011-2003 change	2019	2019-2011 change
Water bodies	131688	164674	32986	134982	-29692
Bare and built-up areas	5987530	6004925	17395	6070263	65338
Shrub lands	204675	181440	-23235	152340	-29100
Crop fields	98051	75172	-22879	58505	-16667
Dense vegetation	12007	7741	-4266	17789	10048

Table 2. Land cover categories

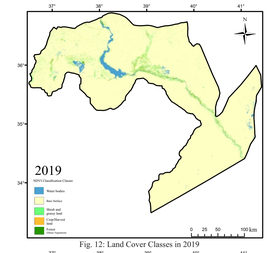

Fig. 12: Land Cover Classes in 2019

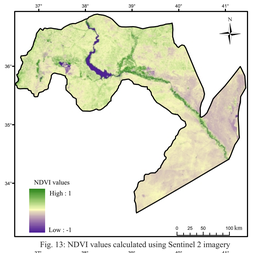

Fig. 13: NDVI values calculated using Sentinel 2 imagery

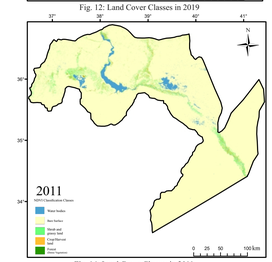

Fig. 14: Land Cover Classes in 2011

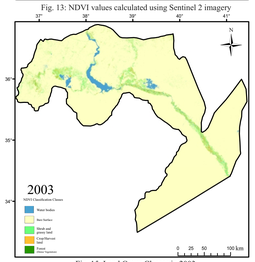

Fig. 15: Land Cover Classes in 2003

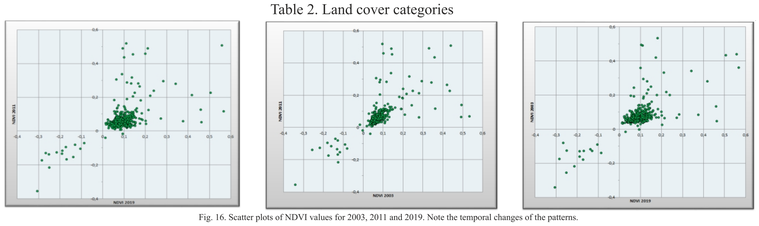

Fig. 16. Scatter plots of NDVI values for 2003, 2011 and 2019. Note the temporal changes of the patterns.

The three NDVI scatter plots show that most of the values in line with each other (the center of the mass is mainly between 0 and 0.2) whereas a slight difference representing with the rest of the values which can be in corresponding with the differences in surface temperature between the three periods as Syria had one of the strongest drought waves in 2006 which led to the broad collapse of farming in northeastern Syria.

The water bodies area first increased by 32986 hectare then the area has decreased to 134982 hectare in 2019. The mentioned decrease (in both green cover and water bodies) can be linked to natural causes representing by drought waves and climate change but also to the effect of the armed conflict in Syrian and the crises which started in 2011 and affects land use and agricultural activity in areas.

Conclusions

This study used remote sensing data and geospatial techniques to calculate different morphometric parameters within the Euphrates river basin in Syria and analyse the relationship between NDVI values which calculated using Sentinel imageries and different terrain attributes in the study area which allow us to better understand the hydrological and geomorphological characteristics of the Euphrates basin.

The results showed that topography had a relative influence on the distribution of vegetation in the study area.

This study also analyzed the changes in land cover over 16 years and classify the land cover into five different classes based on NDVI values.

The results show that the study area get affected by a general decrease of water bodies and green cover, especially during the 2011-2019 period, which not only interpreted by the climate conditions of the study area but also the negative role of the armed conflict in Syria which has started in 2011.

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