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LAND COVER CHANGE INVESTIGATION IN THE SOUTHERN SYRIAN COASTAL BASINS DURING THE PAST 30-YEARS USING LANDSAT REMOTE SENSING DATA

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Abstract

Land cover change and deforestation are important global ecosystem hazards. As for Syria, the current conflict and the subsequent absence of the forest preservation are main reasons for land cover change. This study aims to investigate the temporal and spatial aspects and trends of the land cover alterations in the southern Syrian coastal basins. In this study, land cover maps were made from surface reflectance images of Landsat-5(TM), Landsat-7(ETM$^+$) and Landsat-8(OLI) during May (period of maximum vegetation cover) in 1987, 2002 and 2017. The images were classified into four different thematic classes using the maximum likelihood supervised classification method. The classification results were validated using 160 validation points in 2017, where overall accuracy was 83.75%. Spatial analysis was applied to investigate the land cover change during the period of 30 years for each basin and the whole study area. The results show 262.40 km^2 reduction of forest and natural vegetation area during (1987-2017) period, and 72.5% of this reduction occurred during (2002-2017) period due to over-cutting of forest trees as a source of heating by local people, especially during the conflict period. This reduction was particularly high in the Alabrash and Hseen basins with 76.13 and 79.49 km^2 respectively, and was accompanied by major increase of agriculture lands area which is attributed to dam construction in these basins which allowed people to cultivate rural lands for subsistence or to enhance their economic situation. The results of this study must draw the relevant authorities' attention to preserve the remaining forest area.

Keywords: basins, land cover, remote sensing, supervised classification, Syria

INTRODUCTION

The rate of global urbanization is exponentially increasing, causing damage and reducing areas of natural vegetation (Hussein et al., 2017; López et al., 2001). Monitoring changes in land cover and understanding its spatial properties will lead to an accurate and deep understanding of how human activity affects the general ecological state of the environment (Stow and Chen, 2002; Yeh and Li, 1999). Nevertheless, the deterioration of rural area resources happens quickly, particularly in developing countries (Sarma and Saikia, 2012). In the Mediterranean area, a significant decrease in precipitation amount during the 21st century has been predicted (Lelieveld et al., 2012; Rohde et al., 2013). The decrease in total annual rainfall is expected to reach 20% by the year 2050 (Evans, 2009; Gonçalves et al., 2014). As for Syria, the current conflict and the subsequent absence of the preservation of forests and natural vegetation by the relevant authorities has played an important negative role in land cover changes (LCC). Unfortunately, there is little data available regarding the temporal and spatial aspects of land cover change in the coastal basins, however they would be important because monitoring can helps guiding sustainable development processes especially in rural areas (Marh, 1998). Sustainable development processes through appropriate basins management must take into consideration the complex interactions between human and biophysical processes which can have harmful far-reaching effects on the environment, as well as on economic activities (Panigrahi and Goyal, 2017). Hence, contemporary basins management as part of regional planning processes should include the security of the landscape and respect for the values of biodiversity (Goettle, 2002).

Remote sensing data has become an effective data source in land cover change monitoring studies. In the course of data processing, several pre-calibrated and evaluated products are generated and can be obtained free of charge (Gulácsi and Kovács, 2015). Remote sensing data and ArcGIS tools are extensively used to map and analyse land cover changes in river basins. The maximum likelihood classifier (MLC) algorithm of the supervised classification method is applicable to generate land cover maps. Basically, this supervised classification algorithm uses training sites of different land cover types for land cover mapping. In general, selecting training sites usually requires considerable time and effort and depends on the experience of the analyst and on the quality of the imagery (Aronoff, 2005). Moreover, supervised classification requires a priori knowledge about the land cover types in the study area to achieve appropriate training sites and an accurate signature file in order to derive the required land cover maps.

This empirical study attempts to identify the spatiotemporal pattern of land cover change for southern coastal river basins in Syria as study area using geospatial data. The main objective is to explore the land cover changes using multi-temporal remote sensing data with the help of geographic information system (GIS).

Specifically, the objectives are: (a) to accurately map the extent of the different land cover types in the whole study area in 1987, 2002 and 2017; (b) to detect and evaluate the land cover changes during the last 30 years; (c) to accurately map the extent of the different land cover types for the four coastal basins in the study area in 1987, 2002 and 2017; (d) to detect and evaluate the land cover changes for each basin in the study period; and (e) to conclude on the main processes and the background reasons of each land cover change pattern. The resulted maps, patterns and trends are useful information for the scientific community and decision makers to support spatial planning and sustainable development in this region.

STUDY AREA

The study area is a part of Tartous governorate in the Southern part of Syrian coastal region. It lies between latitudes 34.6438°, 35.0517° and longitudes 35.8494°, 36.3225° covering a total area of 1022 km^2. It has four river basins, of which two major river basins are the Alabrash river basin and the Hseen river basin, and two secondary river basins which are the Ghamqa river basin and the Mntar river basin (Fig. 1).

The strong influence of the Mediterranean climate brings high annual precipitation of more than 800 mm. The precipitation period is from October to May, and the dry and hot summer period lasts from June to September (Abou Zakhem and Hafez, 2010). Elevation data from the Shuttle Radar Topographic Mission (SRTM) with a spatial resolution of 1 arc-second (approximately 30m at the equator), which can be downloaded free of charge through the United States geological survey official website (USGS, 2017), were used to derive the digital elevation model (DEM) and slope maps of the study area. SRTM DEMs data are in geographic decimal degrees (Latitude and Longitude) projection, with WGS84 horizontal datum and EGM96 vertical datum. SRTM DEMs are expected to have a linear vertical absolute height error of less than 16 m, a circular absolute geolocation error of less than 20 m, and a circular relative geolocation error of less than 15 m (Farr et al., 2007). The highest elevation in the study area reaches 1093 m above the sea level in the northeast, and the maximum slope value of the study area reaches 56.4° (Fig. 2).

Depending on the values of both the elevation and the slope in the study area, the study area can be divided into three main parts: the mountains, the plateaus and the coastal areas. The mountain area is located in the northeast and east of the study area

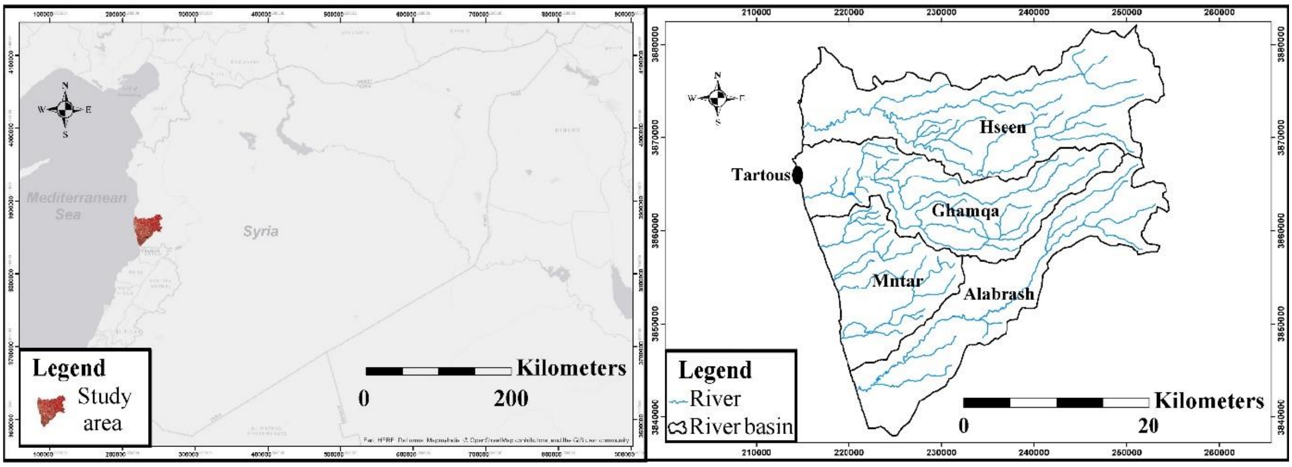

Fig. 1 The location of the study area and its four river basins

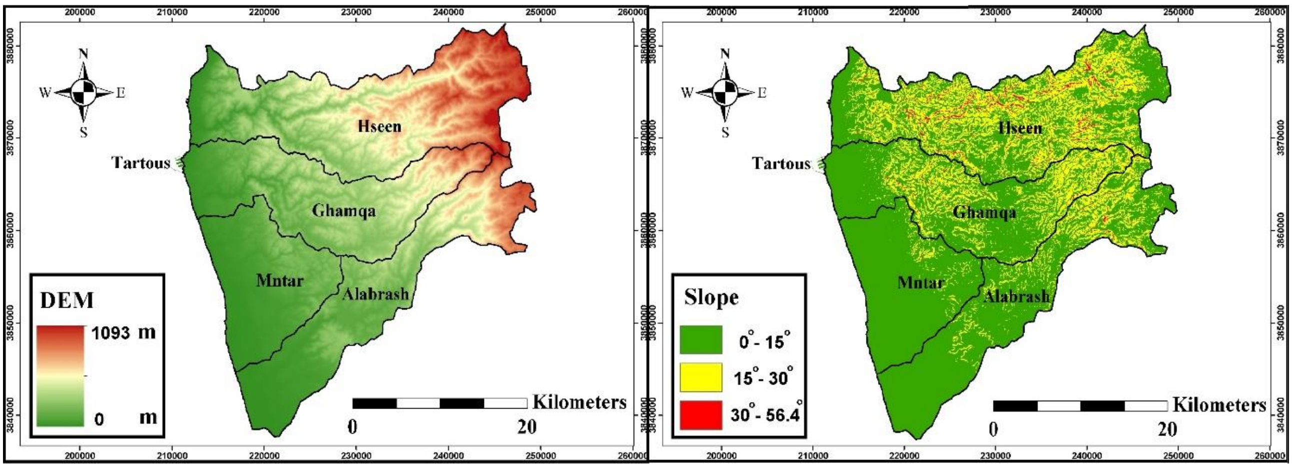

Fig. 2 DEM and slope map of the study area

between 600 m and 1093 m above the sea level, and has slopes reaching to maximum 56.4°. The mountains have good natural water resources due to the existence of many springs. In addition to widespread coniferous forests, this part has also small separate settlements with simple rural agricultural lifestyle depending on planting fruit trees and vegetables. The plateaus area is located between 200 m and 600 m above sea level, where the slope decreases and rivers become wider and broad leaved trees and olive trees are abundant, and it forms the wide home for the people in the rural areas of the Syrian coastal mountains. In this part, construction works of the biggest dam in this area, the Alabrash dam, were started in 1997 and completed in 2000. The irrigation network from this dam helps to irrigate about 10160 hectares of downstream agricultural land (Samoudi, 2015). The coastal area is located between 0 m and 200 m above the sea level and has slopes less than 15°. Tartous port is the main commercial port in this part and all of the study area. This port is located in the north of the study area in Tartous city which is the main and largest city in the study area. The Akkar plain, a fertile plain with different field crops and greenhouses, can be found in this part too.

METHODS

To analyze 30-year of land cover change, Landsat surface reflectance (SR) images were ordered free of charge through the USGS official website (USGS 2017) for getting systematic, radiometric, and geometric corrected higher-level products of the study area from Landsat-5 TM (Thematic Mapper), Landsat-7 ETM$^+$ (Enhanced Thematic Mapper Plus) and Landsat-8 OLI (Operational Land Imager) instruments data with a spatial resolution of 28.5, 30 and 30 m respectively for each VNIR multispectral band (Table 1). For the long-term assessment process, all Landsat images were selected during May to ensure maximum vegetation cover during this reference period.

The Landsat images were preprocessed individually using ArcGIS 10.2 software. They were resampled to the same 30-meter resolution, and a subset of the study area from each image was created and re-projected to the same UTM 36N zone. After that, 150 well distributed training sites representing all the main land cover classes were selected in each processed Landsat image for the supervised classification method which was applied in this study using the common maximum likelihood classifier (MLC) algorithm. This algorithm examines the probability function of a pixel for each of the classes and assigns the pixel to the class with the highest probability (Lillesand and Kiefer, 1994). Four main land cover classes (built-up area, forest and natural vegetation, agriculture lands, and water body) were identified and used to classify the images. Furthermore, the overall accuracy of the results of the whole study area and the user accuracy of each class were calculated using an error matrix of the validation data set (Congalton, 1991). After that, spatial statistics were calculated for each land cover class and thematic maps for land cover and land cover changes were generated. Finally, land cover changes in the whole study area and in each basin during the period of 30 years (1987-2017) were evaluated.

Table 1 The three Landsat images used in this study

Image acquisition date	Sensor (imagery ID)	Resolution
26 May 1987	Landsat5 TM (p174r36_5t19870526)	28.5 m
11 May 2002	Landsat7 ETM+ (LE71740362002131SGS00)	30 m
28 May 2017	Landsat8 OLI/TIRS (LC81740362017148LGN00)	30 m

RESULTS

The resulted land cover maps for the three years 1987, 2002 and 2017 are demonstrated based on the Landsat 5-TM, 7-ETM$^+$ and 8-OLI on Figure 3. The land cover maps show that there is no water body class pattern in 1987 land cover map since there was no dam yet in the study area at that year. However, the 1987 land cover map shows that there is a high ratio of the forest and natural vegetation class, in contrast to 2017 land cover map where the higher ratio of agricultural areas and the decrease of forest and natural vegetation areas. All the land cover maps show that most urban areas are located along the sea shore and increase obviously around Tartous city and the big towns.

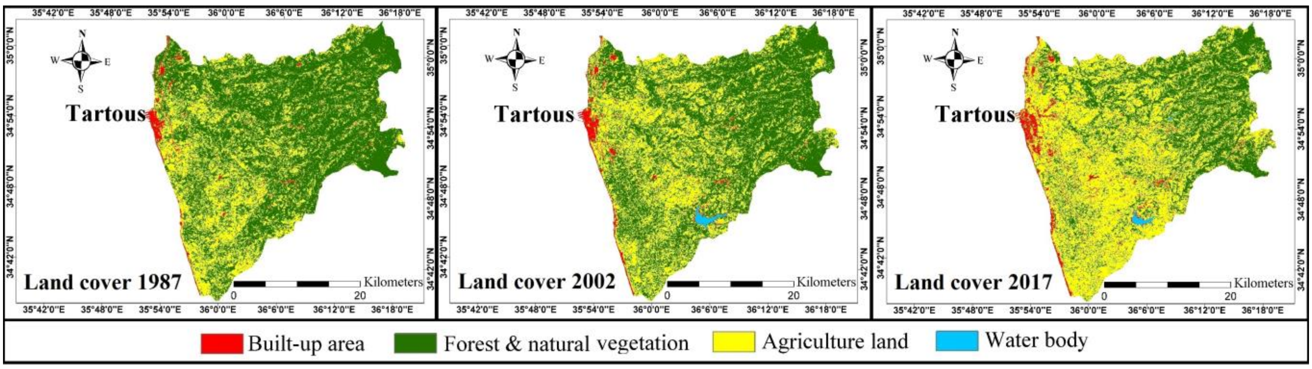

Fig. 3 Land cover maps for 1987, 2002 and 2017 from Landsat 5-TM, 7-ETM$^+$ and 8-OLI images respectively

Since there was no ancillary data available for 1987 and 2002, visual interpretation on the satellite images was applied to select the training data based on detailed local knowledge of the study area. On the other hand, a total of 160 sampling points were randomly created and used as independent data set for the validation process of the land cover map of 2017 (Fig. 4).

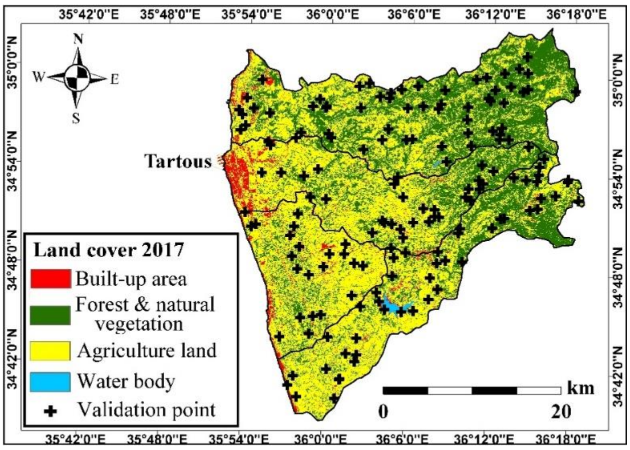

Fig. 4 Distribution of validation points on the land cover map of 2017

In order to check the validation points, a field work was executed in 2017. The observed and computed classes at the validation points in the land cover map of 2017 were used to create an accuracy matrix providing the user accuracy for each class and the overall accuracy. User accuracy was calculated by dividing the number of correctly classified pixels in one class by the total number of validation sets in that class (Congalton, 1991). The user accuracies of the built-up area and the agriculture lands classes were around 75%, while the user accuracy of the forest and natural vegetation class was 96.80% and for the water body class it was 100%. After that, the overall accuracy was calculated from the average total of all user accuracies. The overall accuracy of land cover map 2017 was 83.75% (Table 2).

Spatial analysis for all land cover maps of 1987, 2002 and 2017 was applied to calculate the different areas of each land cover class in order to investigate alterations in land cover. The area of each land cover class was calculated in square kilometers (Table 3), and as the percentage of the total study area (Fig. 5). The results were compared to evaluate land cover changes during the 1987-2002 and 2002-2017 periods.

The supervised classification result of the 1987 image shows that the largest area is the forest and natural vegetation class containing 651.84 km^2, which is 63.75% of the total study area, then it is followed by the agriculture lands class with 346.8 km^2 and 33.92% of the total study area. The remaining land cover is the built-up area class with 23.91 km^2 and 2.34% of the total study area. Also, based on the 2002 supervised classification result, the largest area is the forest and natural vegetation class with 579.79 km^2 and 56.70% of the total study area. The agriculture lands cover 407.65 km^2 and 39.87% of the total study area, and the built-up area class covers 30.06 km^2 and 2.94% of the total study area. The remaining land cover is water body with 5.06 km^2 and 0.49% of the total study area. In contrast, the 2017 supervised classification result shows that the largest area is the agriculture lands class with 582.70 km^2 and 56.98% of the total study area, followed by the forest and natural vegetation class with 389.44 km^2 and 38.08% of the total study area, and the built-up area class with 46.69 km^2 and 4.57% of the total study area. The remaining land cover is water body with 3.73 km^2 and 0.36% of the total study area.

Table 3 Land cover classes area in 1987, 2002 and 2017 in km^2

Land cover classes	**1987**	**2002**	**2017**
	Area (km^2)	Area (km^2)	Area (km^2)
Built-up area	23.91	30.06	46.69
Forest & natural vegetation	651.84	579.79	389.44
Agriculture lands	346.80	407.65	582.70
Water body	0	5.06	3.73

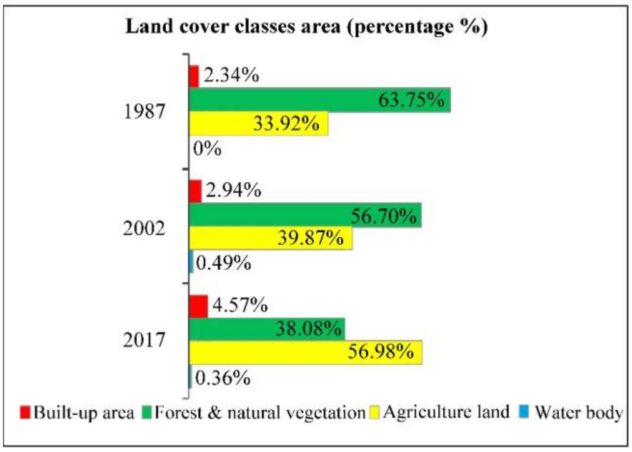

Fig. 5 Land cover classes area in 1987, 2002 and 2017 in percentage of the total study area

Table 2 Classification accuracies for land cover map 2017

Class Name	**class**	**1**	**2**	**3**	**4**	**User Accuracy**	**Validation points**
Built-up area	**1**	3	0	1	0	75%	4
Forest & natural vegetation	**2**	0	60	2	0	96.80%	62
Agriculture lands	**3**	0	23	70	0	75.30%	93
Water body	**4**	0	0	0	1	100%	1
Overall Accuracy						**83.75%**	**160 Total**

Table 4 The land cover change of the whole study area between 1987 and 2017

Land cover classes	Land cover change 1987-2002		Land cover change 2002-2017		Land cover change 1987-2017	
	km^2	%	km^2	%	km^2	%
Built-up area	6.14	0.60	16.63	1.62	22.77	2.22
Forest & natural vegetation	-72.05	-7.04	-190.35	-18.61	-262.40	-25.66
Agriculture lands	60.84	5.95	175.05	17.11	235.90	23.06
Water body	5.05	0.49	-1.329	-0.13	3.73	0.36

DISCUSSION

The study area as a whole is subject to a general decrease of natural vegetation. The largest change in land cover type was the reduction of the forest and natural vegetation class with an amount of loss reaching 262.40 km^2 out of 651.84 km^2 which is equal to almost 40% of the area of this class, and 25.66% of the total study area. Almost 72.5% of this reduction occurred during the 2002-2017 period, and just 27.5% of it occurred during the 1987-2002 period. This reduction is most likely caused by over-cutting of forest trees over time and especially during the recent conflict period and the subsequent absence of the preservation of the forest and natural vegetation. At the same time, the agriculture lands class area increased 235.90 km^2 which can be attributed to the attempts of local people to cultivate more land in rural areas for subsistence or to enhance their economic situation. Meanwhile, the area of the built-up area class has increased with 22.77 km^2 till 2017 which is almost double that of the 1987 area. However, it must be mentioned that the Alabrash dam has entered in service in 2000. So, the water body areas here represent the reservoir area in which the storage of the water is related to the annual amount of the rainfall and the irrigation operations from the dam.

The forest and natural vegetation class showed the largest land cover change, it is representative of natural vegetation in the study area. Therefore, spatial analysis was applied on the land cover changes of this class in order to evaluate the detailed trends of the changes in this class during the two main periods of the study 1987-2002 and 2002-2017 (Fig.6).

The results show that the forest and natural vegetation class lost 29.03% of its area between 1987 and 2002, while this loss reached 42.66% between 2002 and 2017 (Table 5). This increasing value reflects not only the climate change during the second period but also the negative role of the current conflict in Syria and the subsequent absence of the preservation of the forests and natural vegetation.

Land cover change analyses were executed for each basin in the study area and the results show that the Alabrash basin has the maximum forest and natural vegetation area decline in percentage relative to the basin area with 30.98%. At the same time, the Hseen basin has the maximum forest and natural vegetation area decline in square kilometres with 79.49 km^2 reduction. Meanwhile, the Mntar basin has the minimum forest and natural vegetation area decline in both square kilometres and percentage relative to the basin area with 36.92 km^2 and 21.70% respectively. Moreover, the major increase of agriculture land area could be seen also in the both Alabrash and Hseen basins with 67.65 km^2 and 77.52 km^2 respectively (Table 6). This can be attributed to the dam construction processes in these two basins in the late nineties which allowed many local people to cultivate more rural lands to enhance their economic situation or even for subsistence during the current conflict period. This increase of the agricultural land area here at the expense of the forest and natural vegetation area can be considered as a negative change in the ecosystem of the area as it most likely indicates the possibility of the built area growth in a later stage.

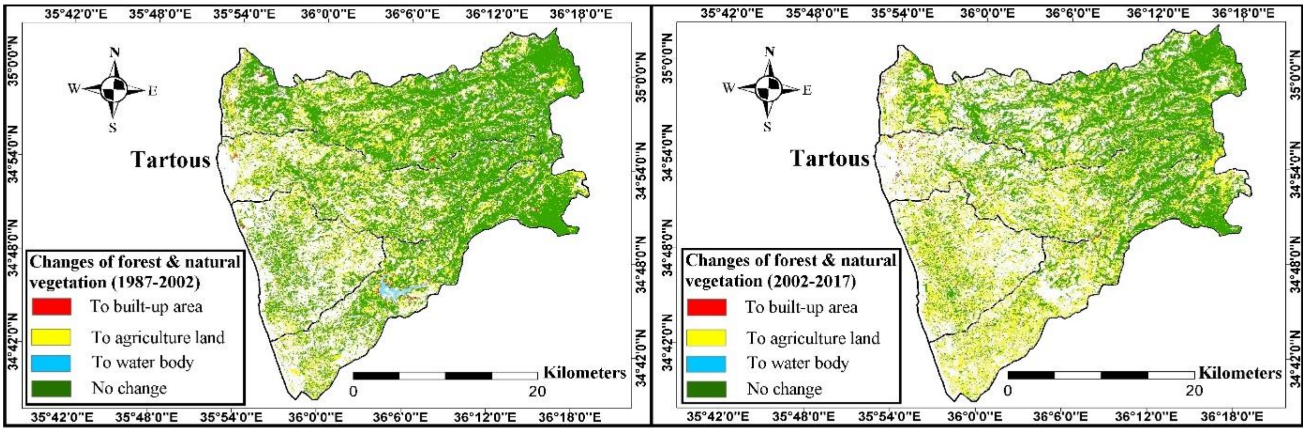

Fig. 6 Changes of forest & natural vegetation class during the 1987-2002 and 2002-2017 periods

Table 5 Patterns of forest & natural vegetation change during the 1987-2002 and 2002-2017 periods

Patterns of forest & natural vegetation change	**Area in (%) of total forest & natural vegetation class area (1987-2002)**	**Area in (%) of total forest & natural vegetation class area (2002-2017)**
Forest & natural vegetation to built-up area	0.73	1.10
Forest & natural vegetation to agriculture lands	28.65	41.53
Forest & natural vegetation to water body	0.52	0.02
No change	70.07	57.34

Also, the result of land cover change analyses for each basin in the study area shows that the Hseen basin has the smallest built-up area increase in both square kilometres and percentage relative to the basin area with 1.53 km^2 and 0.42% respectively. While, the Mntar basin has the largest built-up area increase in percentage relative to the basin area with a 4.29% increase within the basin. At the same time, the Ghamqa basin has the maximum built-up area increase in square kilometres with 8.62 km^2 increase within the basin. This increase of the built-up area in these basins is related to the growth of Tartous city in addition to the big towns and villages in the study area especially during the last few years after the arrival of large numbers of displaced families who were forced to flee their homes from the interior regions of Syria due to the current conflict. So, the attempt of some local people and real estate traders to make benefits from accommodate these families plays a main role in the growth of the construction works in these areas.

Table 6 The land cover changes of each basin during the period of study (1987-2017)

Land cover classes	**1987**		**2017**		**LCC 1987-2017**	
	Area km^2	**Area %**	**Area km^2**	**Area %**	**Change km^2**	**Change %**
Alabrash Basin (245.77 km^2)						
Built-up area	2.98	1.21	8.29	3.37	5.31	2.16
Forest & natural vegetation	159.93	65.07	83.79	34.09	-76.13	-30.98
Agriculture lands	82.85	33.71	150.50	61.22	67.65	27.51
Water body	0	0	3.20	1.30	3.20	1.30
Hseen Basin (357.82 km^2)						
Built-up area	6.98	1.95	8.51	2.38	1.53	0.42
Forest & natural vegetation	270.85	75.69	191.36	53.48	-79.49	-22.20
Agriculture lands	79.98	22.35	157.50	44.02	77.52	21.67
Water body	0	0	0.38	0.10	0.38	0.10
Ghamqa Basin (248.98 km^2)						
Built-up area	10.29	4.13	18.92	7.60	8.62	3.46
Forest & natural vegetation	149.00	59.84	79.12	31.78	-69.88	-28.05
Agriculture lands	89.68	36.01	150.86	60.60	61.18	24.58
Water body	0	0	0	0	0	0
Mntar Basin (170.03 km^2)						
Built-up area	3.65	2.15	10.95	6.44	7.29	4.29
Forest & natural vegetation	72.07	42.38	35.15	20.68	-36.92	-21.70
Agriculture lands	94.30	55.46	123.83	72.86	29.52	17.40
Water body	0	0	0	0	0	0

CONCLUSION

This study analyzed the changes in land cover of the southern Syrian coastal basins during the last 30 years, based on multi-temporal Landsat surface reflectance images from three different dates in 1987, 2002 and 2017. Supervised classification method was applied using the common maximum likelihood classifier (MLC) algorithm to classify each Landsat image into four land cover classes. Spatial analysis on each land cover map of 1987, 2002 and 2017 was applied to calculate the different areas of each land cover class in order to investigate their changes during the study period. The results show that the study area is strongly affected by a general decrease of forest and natural vegetation, especially during the 2002-2017 period, which not only reflects the climate change, but also the negative role of the current conflict in Syria. The main reasons for the decrease in the forest and natural vegetation in the study area are over-cutting of forest trees due to the absence of the forest and natural vegetation preservation by the relevant authorities, and also the attempts of local people in this area to cultivate more lands in rural areas either for subsistence or to enhance their economic situation. The results of this study must draw attention of the relevant authorities to put urgent plans to preserve the remaining forest area, and also to put long-term strategies to restore the forest area that has been lost so far within the whole coastal region in general, and within the southern coastal basins in particular. Also, more studies on the impact of the war in Syria on land cover change as well as on the long-term implications of climate change must be carried out because the exact knowledge of spatial patterns and trends may help guiding sustainable development processes especially in the rural areas.

Acknowledgements

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