Mapping Deforestation by Multitemperal Data using Remote Sensing Technologies, Sinop-Turkey Case Study

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Key words: Remote sensing, NDVI, Change Detection, Deforestation, Sinop-Turkey

SUMMARY

Forests are playing significant role not only animals but also for humans and their following generation in terms of ecological issues. In the last two decades, deforestation and forest degradation issues have increased. Since 1960s' over the half of the tropical forests have been destroyed and deforestation rate has been increased rapidly. In the last decade, 13 million of ha/year of forests have been deforested in the world and the rate of the forest degradation is extremely high.

This paper intends to map Land Use Land Cover (LULC) changes and forest degradation derived from Landsat satellite images using remote sensing technologies. For this aim, Sinop province of Turkey was selected as the case study area. Sinop province is located among Turkey's most northern tip Inceburun which is surrounded by Kastamonu in the west, Çorum in the south, Samsun in the east and Black Sea in the north. The city is situated between 34°13'59.73" - 35°27'17.83" Eastern Meridians and 41°42'32.61" - 41°20'19.68" Northern Parallels with an altitude of 25m. above sea level.

LULC changes and forest degradation have been studied using Landsat data sets between the years 1987-2019. 3 Landsat 5 TM imageries were dated 27 July 1987, 06 July 1997 and 16 June 2007 and 2 Landsat 8 OLI/TIRS imageries were dated 13 July 2017 and 10 July 2019. In this context, Support Vector Machine algorithm which is the most trusted supervised classification method and Normalized Difference Vegetation Index (NDVI) were applied to all Landsat data to demonstrate forest and built-up changes in every decade. Seven land use classes were selected which were; Waterbody, agriculture, sand, built-up areas, vegetation, forest and bare soil/rock. Noteworthy changes were observed in the classes of built-up areas and forest from the year of 1987 to 2019. Besides, accuracy assessments were carried out and the kappa statistics for Landsat 5 and Landsat 8 data were calculated 0.94, 0.99, 0.89, 0.98 and 0.99

respectively. Unfortunately, in the case study area, forest degradation will be continued due to the installation of nuclear power plant station in the following years.

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1. INTRODUCTION

Forest degradation and deforestation are the most dangerous threat for the forests of the whole world. Since 1960s' over the half of the tropical forests have been destroyed and deforestation rate has been increased rapidly. In the last decade, 13 million of ha/year of forests have been deforested in the world and the rate of the forest degradation is extremely high [1]. Forests are playing significant role not only animals but also for humans and their following generation in terms of ecological issues. In Turkey, the total amount of forest and forest areas are 27 million ha and only 1.6% of this figure is under protection. Turkey is among the richest countries in the world in terms of different plant species. An estimated more than 10,000 vascular plants live in the territory of Turkey and about 34% of them were classified as endemic species [2-3- 4]. The most important algorithm to detect Land Use Land Cover changes over time is remote sensing nowadays. In the literature, remote sensing approaches have been used in order to detect land use land cover changes in time and scale in many significant scientific papers. Besides using Remote sensing approaches in LULC changes over time gives opportunity to get results with low costs, less time consumption and better accuracy. This technique also allows scientists to update results when the new data is available [5-6-7].

2. STUDY AREA & DATA SETS

Sinop province is located among Turkey's most northern tip Inceburun which is surrounded by Kastamonu in the west, Çorum in the south, Samsun in the east and Black Sea in the north. The city is situated between 34°13'59.73" - 35°27'17.83" Eastern Meridians and 41°42'32.61" - 41°20'19.68" Northern Parallels with an altitude of 25m. above sea level. Besides, the province area covers about 5860 km2 of the total land of Turkey. (Fig. 1) Sinop province is dominated densely forested areas and vegetation as it receives highly rainfall during most part of the season. Besides, three important parks are situated in the border of Sinop province. These are Bozburun Wildlife Development Area; Hamsilos Nature Park, and Sarıkum Nature Reserve [8]. In Sinop Peninsula, the Sinop Nuclear Power Plant has been constructed. The Nuclear Power plant includes 4 different reactors. The first unit of the construction will be completed by 2023 and the final phase will be finished and activated by 2028. Thus this construction will cause important environmental changes in the study area [9].

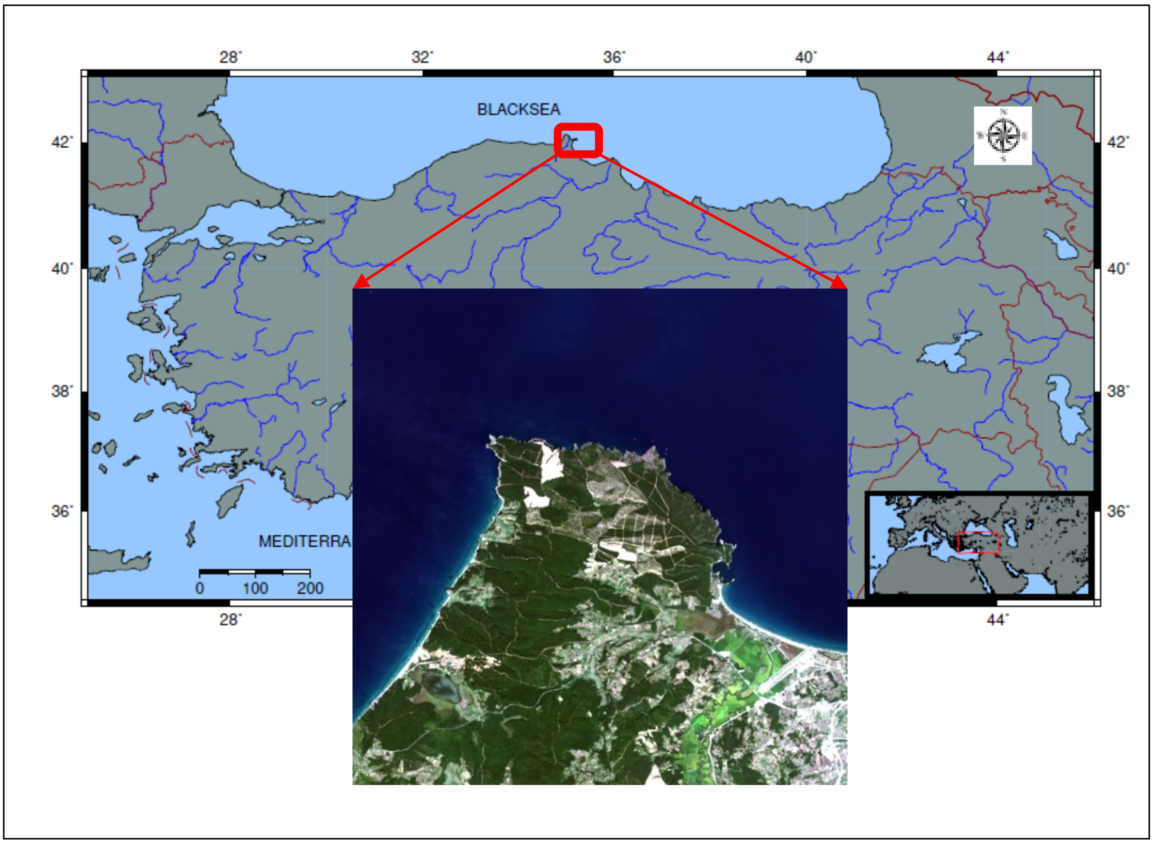

Figure 1. The geographical location of the study area.

During the remote sensing analysis, multi-temporal data were used to detect the extent of forest degradation in the region in the long term. In the analyses, 3 Landsat 5 TM which were dated at 27 July 1987, 06 July 1997 and 16 June 2007 and 2 Landsat 8 OLI/TIRS data which were dated at 13 July 2017 and 10 July 2019 acquired from USGS Archive [10]. These data were used to map and evaluate the decadal land cover changes due to the forest degradation. All optical satellite data belonging to nearly or almost to the same season in order to avoid the seasonal changes as much as possible. Besides all data cloud coverage was lower than 10 %. The specifications of the used satellite images acquired for forest degradation and LULC change detection are given in the Table 1.

Bands	Landsat 5 TM		Landsat 8 OLI/TIRS	
	Spectral Resolution (µm)	Spatial Resolution (m)	Spectral Resolution (µm)	Spatial Resolution (m)
B1	0.45 - 0.52	30	0.435-0.451	30
B2	0.52 - 0.60	30	0.452-0.512	30
B3	0.63 – 0.69	30	0.533-0.590	30
B4	0.76 – 0.90	30	0.636-0.673	30
B5	1.55 – 1.75	30	0.851-0.879	30
B6	10.40 – 12.50	120* (30)	1.566-1.651	30
B7	2.08 – 2.35	30	2.107-2.294	30
B8	-	-	0.503-0.676	15 (Pan.)
B9	-	-	1.363 -1.384	30
B10	-	-	10.60 -11.19	100*
B11	-	-	11.50 -12.51	100*
*TM Band 6 was acquired at 120-meter resolution, but products are resampled to 30-meter pixels. *TIR bands are acquired at 100 m. resolution, and resampled to 30 min delivered data product.				

Table 1. The characteristics of Landsat 5 and Landsat 8 datasets used in this study.

3. METHODOLOGY

In the literature, there are numerous classification approaches that have been developed and widely used. In this study, the most trusted and reliable pixel based image analysis classification method which is Support Vector Machine (SVM) algorithm was used. SVM is a machine learning image analysis classification method that is used in many different areas. SVM pixel based classification and spectral vegetation index (NDVI) were the two different steps to evaluate the results of the case study forest degradation quantitatively and qualitatively. All analyses were performed in this study for SVM classification and its accuracy assessment via ENVI version 4.8 (Exelis Vis. Inf.Sol.) and NDVI calculation using ArcGIS v.10.0 (ESRI) software packages.

a. Image Classification – Support Vector Machine Algorithm

The fundemantal of SVM algorithm is to find an optimal boundary which is represented by a hyperplane in the feature space between two classes due to minimize the classification error [11]. SVM is one of the most known non-parametric classification algorithm that has been performed widely in terms of classification process in remote sensing [12,13,14].
The main LULC classes identified in Sinop Peninsula through the image analysis are Vegetation, Forest, Built-up, Agriculture land, Bare soil and Rocky, Waterbody, Sand. Vegetation cover represents lands with herbaceous types of cover while forest cover represents lands dominated by woody vegetation such as deciduous and evergreen forests. Built-up class is defined as land covered by structures and other man – made structures such as buildings, dams, roads, asphalts. Agriculture land cover represents areas where the dominated fields are related to agriculture. Bare soil and rocky surface represent the lands with exposed soil, rocks etc. which are observed near the sea side in general. Waterbody class is the biggest class that covers the sea, small and big, natural or artificial fresh and salt water bodies in the study area whereas sand class is the smallest one covers the lands with exposed to sands and dune. For the years of 1987-2019, the spatiotemporal changes in the aforementioned features for the case study area are displayed in Fig. 3.

Moreover, Support Vector Machine supervised classification algorithm was used for quantitative analysis of Landsat 5 TM and Landsat 8 OLI/TIRS datasets. A significant phase for the evaluation of the results of SVM classification process is the accuracy assessment. The classification of accuracy was carried out through the confusion matrix and the overall accuracies and Kappa coefficients of the all datasets are shown in Table 2.

Date	Overall Accuracy (%)	Kappa coefficient
1987	96.5962	0.9493
1997	99.9103	0.9913
2007	98.5691	0.8923
2017	99.5356	0.9632
2019	99.2969	0.9559

Table 2: SVM Classification accuracy assessment

b. Normalized Difference Vegetation Index (NDVI) Calculation

Green vegetation performs photosynthesis using chlorophyll in its leaves. During photosynthesis, the portion of the electromagnetic energy from the sun in the wavelength range of 0.63 µm to 0.69 µm corresponding to red light is used. Therefore, a satellite image that measures the reflection of red light will have low numerical values in areas with dense vegetation [15]. Normalized Difference Vegetation Index (NDVI) is the most commonly used index for detecting green vegetation in Remote Sensing applications and monitoring positive and negative results over time. NDVI is the mathematical expression of near infrared and red band images [16] (Formula 1). NDVI is expressed in the range of [-1 to +1]. In vegetation-intensive regions, NDVI approaches to +1, while vegetation is sparse and in bare soil, the NDVI value moves away from + 1 and approaches zero. NDVI index values of different objects such as cloud, water and snow are close to -1 [17].

$$NDVI = (NIR - Red) / (NIR + Red) \qquad \text{Formula 1}$$

NDVI maps for the case study area of the years 1987, 1997, 2007, 2017 and 2019 were produced. NDVI technique was applied to all data to track vegetation coverage and changes in the case study area for the time period. When the NDVI indexed maps were examined, there was a significant forest degredation between 1997-2019 in the region. The forest degradation has started at 1997 and it has reached at its highest value at 2019 (Fig 2).

4. RESULTS & DISCUSSION

This paper used 10-year interval (1987, 1997, 2007, 2017 and 2019) of Landsat data and ancillary NDVI data in order to display the changes in the long run for the case study area. According to LULC change detection analysis and mapping to forest degradation performed for the period of 1987 – 2019, the main change was observed in two classes; forest and built-up. As shown, the findings of this study clearly prove that the negative effects on the forest areas was mainly observed by using satellite images (Table 3). There was a rapid increase in the built-up land cover especially from 2017 to 2019. Analyzing the table 3, it is clearly seen that, forest land cover has been decreased continuously from 1997 to 2019. It was observed that rapid forest degradation occurred in the case study area with a decrease 51 % in forest class and increase 28 % in built-up class from the year 1987 to 2019.

The most spectacular effect of forest degradation is not only the loss of habitat but also loss of endanger species of animals and endemic plants. Besides, forest degradation is helping to change the whole worlds' climate and cause the harmful for the nature of the earth. In recent years, remote sensing products such as optical and radar images are useful for accurately mapping land use land cover analysis. Spectral Vegetation index such as NDVI is the most known index among remote sensing approach. NDVI is the best vegetation index in order to detect the healthy vegetation and forest with satellite images. Support Vector Machine is the best algorithm to detect and evaluate the changes over time in specific location in the long run. As shown in this study, the multi-temporal Landsat 5 TM and Landsat 8 OLI/TIRS satellite images cover the Sinop peninsula and its vicinity have been classified in order to detect and evaluate the land use land cover changes and forest degradation which has been occurred in the decadal period from 1987 to 2019. Noteworthy changes were observed in the classes of built-up areas and forest from the year of 1987 to 2019. Unfortunately it is highly expected that, deforestation in the case study area will continue and cause urbanization due to the Sinop nuclear power plant installation. When all phases of the power plant construction will finish, it will change the land cover land use in Sinop Peninsula and may lead to inevitable environmental problem

Acknowledgements

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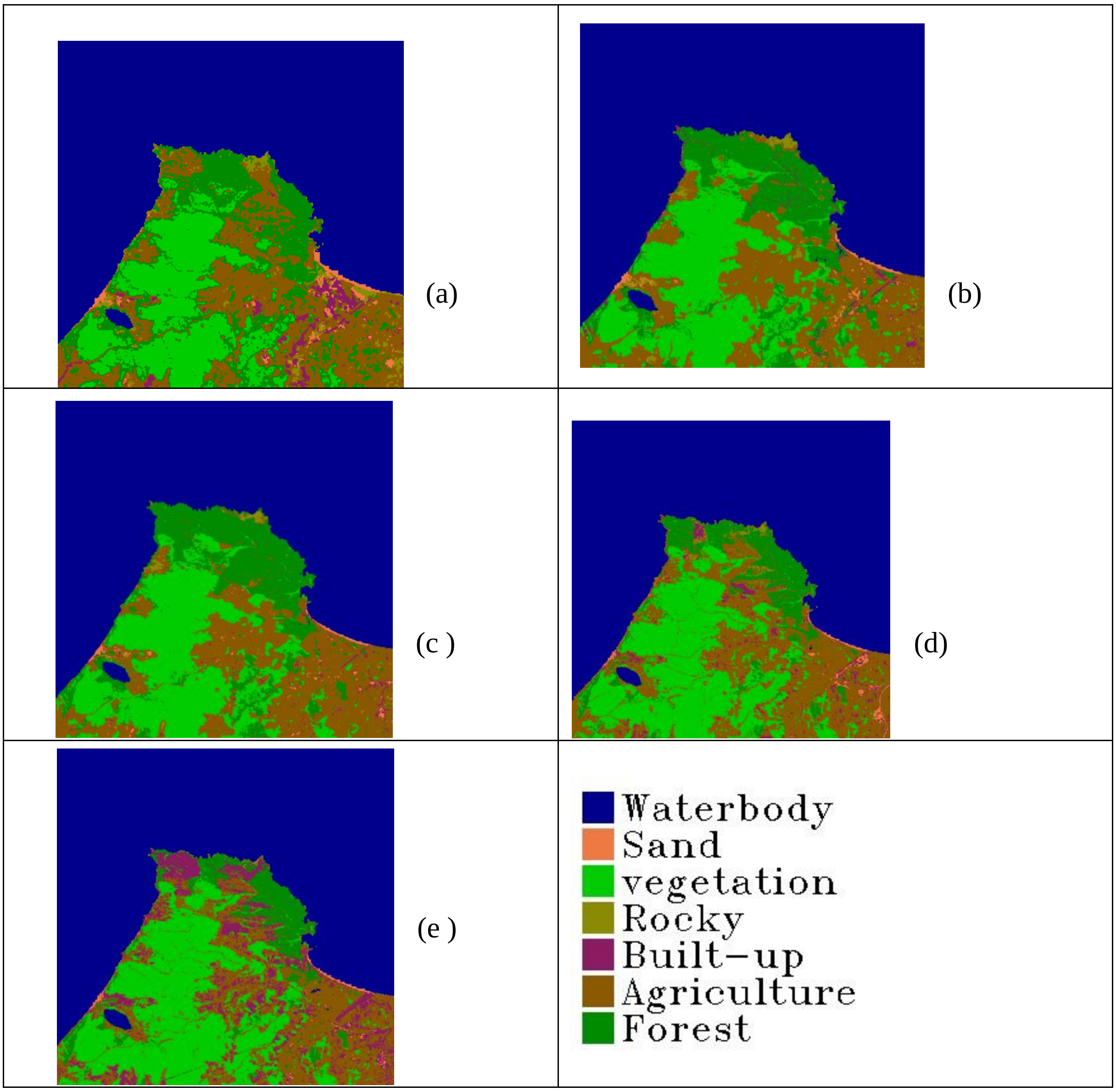

Figure 3: LULC maps of Landsat datasets (© USGS) datasets. (a) 1987. (b) 1997. (c) 2007. (d) 2017. (e) 2019. (f) Definition of the classes.

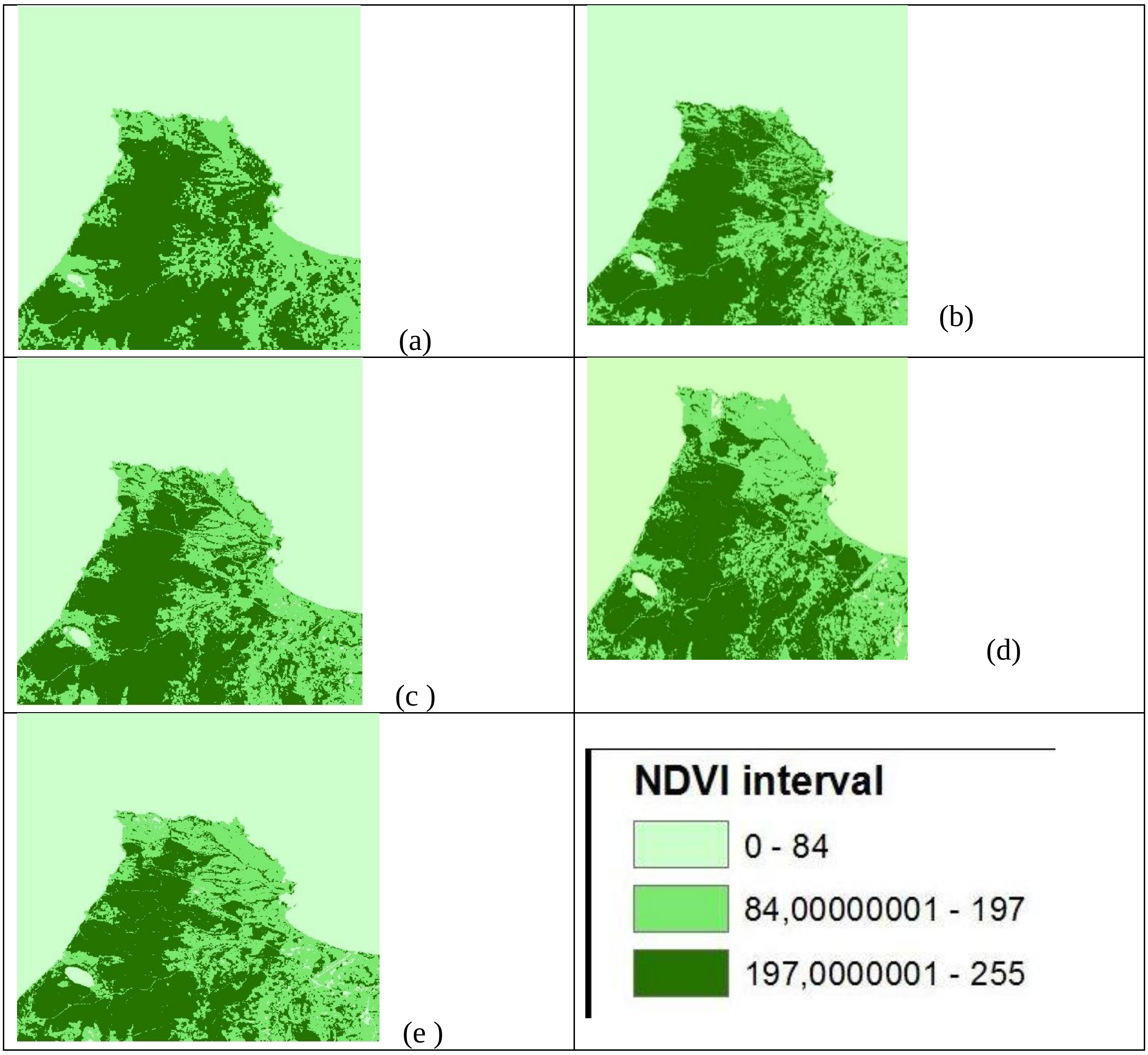

Figure 2. The classification of NDVI (a) 1987. (b) 1997. (c) 2007. (d) 2017. (e) 2019.

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BIOGRAPHICAL NOTES

Asli SABUNCU received a master's degree in Geodesy from Bogazici University KOERI, Istanbul,Turkey in 2010. She gained a Ph.D. degree in the Department of Geomatics Engineering at Istanbul Technical University in 2018. Her research interests are remote sensing and its application, GPS, precise levelling applications and crustal deformations.

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