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Article *in* Disaster Advances · January 2022

DOI: 10.25303/1501da5360

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Detection of forest fire burn-area using landsat-8 and sentinel-2: a case study of Nivale (Kolhapur) beat of Chandoli National Park, Maharashtra, India

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Abstract

Forests play an important role in maintaining environmental equilibrium in the ecosystem. Forest fires, which can occur for a variety of reasons, are the greatest threat to forests. In order to control forest fires, it is critical to assess the formation and behavioral characteristics of forest fires. Detecting fire areas and the severity is much easier with satellite images obtained with advancing technologies. The main objective of this study is to extract burn area from Landsat-8 and Sentinel-2 satellite images of 2017 using six vegetation indices. Remote sensing data was used to study a forest fire in the Nivale (Kolhapur) beat of Chandoli National Park of Maharashtra. The Department of Divisional Forest Officer (Wildlife)-Chandoli National Park at Karad (DDFO-CNP) provided reference data indicating that the fire had damaged 194 hectares of Scrub forest. In addition, forest fire areas were determined using an object-based image classification technique.

When the findings of the study are compared to the values obtained by DDFO- CNP, it is found that Sentinel-2's object-based analysis provided the highest accuracy with an overall accuracy of 84 % and 0.795 Kappa statistics. Landsat-8 image has 82 % overall accuracy and 0.765 Kappa value. The findings of Sentinel-2 and Landsat-8 spectral indices showed the Sentinel-2 had better results in all indices. Differenced Normalized Difference Vegetation Index (dNDVI) and Relative Difference Normalized Burn Ratio (RdNBR) performed better than other indexes with a difference of only 18.27 and 30.88 hectares respectively. According to the fire severity analysis, a burn area with high intensity in Sentinel-2 was identified as moderate-high in Landsat-8. As per the research findings, sentinel-2 had a high severity area of 28.72 ha and a low severity area of 37.04 ha. It shows that satellite images of Sentinel-2 are highly suitable than Landsat-8 for estimating scrub forest fire areas. Finally, the findings of this study could be useful to forest managers to monitor burn regions quickly after the fire and in reducing severity and frequency of forest fires.

Keywords: Forest Fire, Chandoli National Park, Burn Severity, Burn Area, Landsat -8, Sentinel-2

Introduction

Forests are essential for ecosystem and environmental equilibrium because they supply organic infrastructure. It is well-known that global forest cover has decreased dramatically over the previous two decades and forest fire is the main cause of forest degradation. It may not be enough to take the essential precautions on time to fight against forest fires successfully. Furthermore, advanced technology should be employed at all stages of the firefighting process[1]. For a long time, forest fire damage has been detected using remote sensing methods[2]. Remote sensing methods are used to detect burnt areas, to determine the intensity of fires and to manage fires etc. Image classification and fire index methods are commonly used in estimating the temporal change in forest areas and burn severity analysis.

Escuin et al[5] analyzed three separate fires in Southern Spain between 1995 and 2001 using the Normalized Burn Ratio (NBR) and NDVI indexes on Landsat satellite images. The NIR and MIR bands are preferred because they are best for revealing fire characteristics.

Quintano et al[8] used Sentinel-2 and Landsat-8 to assess burn severity using three indices: Differenced normalized burn ratio (dNBR), Relative dNBR (RdNBR) and Relativized Burn Ratio (RBR). The result showed that RdNBR based on Landsat-8 had the best accuracy. Kurnaz et al[6] used Landsat-8 and Sentinel-2 images to determine burn area and burn severity using seven indices including dNBR, dNDVI, dGNDVI, RBR, BAI, GEMI and RdNBR. The accuracy of dNDVI and RdNBR based on Sentinel-2 and Landsat -8 was the best.

In the present research, the performance of Landsat-8 and Sentinel-2 satellite images for determining the burned area in a forest region is studied. The major aim of the present research is to find appropriate satellite images and indices for delineating the burned area and mapping severity. For this analysis, six indices were used: dNBR, RBR, RdNBR, dNDVI, dGNDVI and BAI to assess burn severity and identify the burnt area which is 194 hectares according to DDFO- CNP. The final products were compared to reference data and an accuracy assessment was carried out.

Study Area

There are a total of 30 beats in Chandoli National Park. As the study area, the Nivale (Kolhapur) beat was chosen (Figure 1). It has area of 2277 ha. (22.77 sq. km) out of 57.37% forest area. The park became a national park on May

14, 2004[6]. The park is located at the junction of Satara, Kolhapur, Ratnagiri and Sangli districts. The study region is divided into two geomorphological units: structural origin (moderately dissected lower plateau) and denudation origin (moderately dissected upper plateau). Scrub forest covers a total of 435.03 ha. Moderately deep soil is covered by 94.73 % of the area. The average annual precipitation in the area is 2829.87 mm and average temperature is exceeding 25 degree Celsius. The average elevation is 840 meters above mean sea level (MSL).

Material and Methods

Database: The medium resolution satellite data from the Landsat-8 satellite with 30m resolution was used in this study. The images were collected from the website of the USGS (United States Geological Survey). Landsat-8 is an AEOS (American Earth observation satellite) equipped with the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) sensors. It is series eighth satellite ensuring that the Landsat program's most crucial role of determining and monitoring the resources required for human livelihoods is maintained. In addition, Sentinel-2 satellite data has been used to identify and compare burnt areas to a Landsat- 8 satellite image. SCIHUB (Sentinels Scientific Data Hub) of the European Space Agency (ESA) provided the images without charges.

The Sentinel-2 series includes two satellites: Sentinel 2A and 2B which have 10m spatial resolution. Table 1 summarizes the satellite data that was used for the present study. Sentinel- 2 satellites with their wide lane width, high spatial resolution and 13 spectral bands, provide a unique perspective for viewing vegetation. Table 2 shows spatial and spectral data of the Landsat-8 and Sentinel- 2 satellites[2].

Methodology: For the present research work, the following main workflow steps were followed (Fig. 2). The Nivale (Kolhapur) beat witnessed forest fire on March 15, 2017. The DDFO-CNP, which is associated with the Sahyadri tiger reserve management system, provided data on the duration of fire, start and end dates, GPS coordinates, area of burning land, forest type affected by fire, number of people interfering with the fire etc. Burnt area and intensity were calculated using the Landsat-8 and Sentinel-2 satellite image indexes and variations in detecting the burning area were examined using an object-based classification approach. By using arithmetic calculations of bands, six vegetation indices were considered for the analysis: dNBR, RdNBR, dNDVI, dGNDI, RBR and BAI.

Table 1
Details of Satellite Data

Satellite	Pre fire	Post fire	Path/ Row/ Tile	Band used	Resolution
Landsat -8	12 March 2017	28 March 2017	147/048	2,3,4,5,7	30m
Sentinel -2	1 March 2017	21 March 2017	T43QCU	2,3,4,8,12	10/20m

Table 2
Properties of Landsat-8 and Sentinel-2 satellites

L8 Band		Res. (m)	Wavelength (min-max)	S2 Band		Res. (m)	Wavelength (min-max)
1	C/A	30	0.435-0.451	1	C/A	60	0.421-0.457
2	Blue	30	0.452-0.512	2	Blue	10	0.439-0.535
3	Green	30	0.533-0.590	3	Green	10	0.537-0.582
4	Red	30	0.636-0.673	4	Red	10	0.646-0.685
				5	VER	20	0.694-0.714
				6	VER	20	0.731-0.749
				7	VER	20	0.768-0.796
5	NIR	30	0.851-0.879	8	NIR	10	0.767-0.908
				8a	NIRn2	20	0.848-0.881
				9	WV	60	0.931-0.958
9	Cirrus	30	1.363-1.384	10	Cirrus	60	1.338-1.414
6	SWIR	30	1.567-1.651	11	SWIR	20	1.539-1.681
7	WIR 2	30	2.107-2.294	12	SWIR2	20	2.072-2.312
8	Pan	15	0.503-0.676				
10	TIRS	100	10.60-11.19				
11	TIRS	100	11.50-12.51				

(Source of table - Bahadir Kurnaz and et al, May 2020)

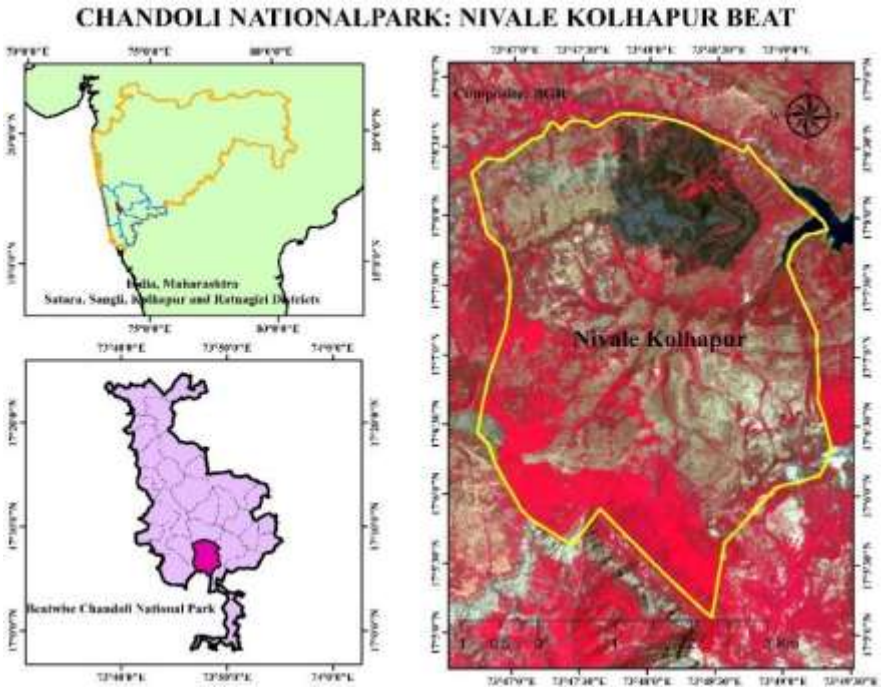

Figure 1: Study Area

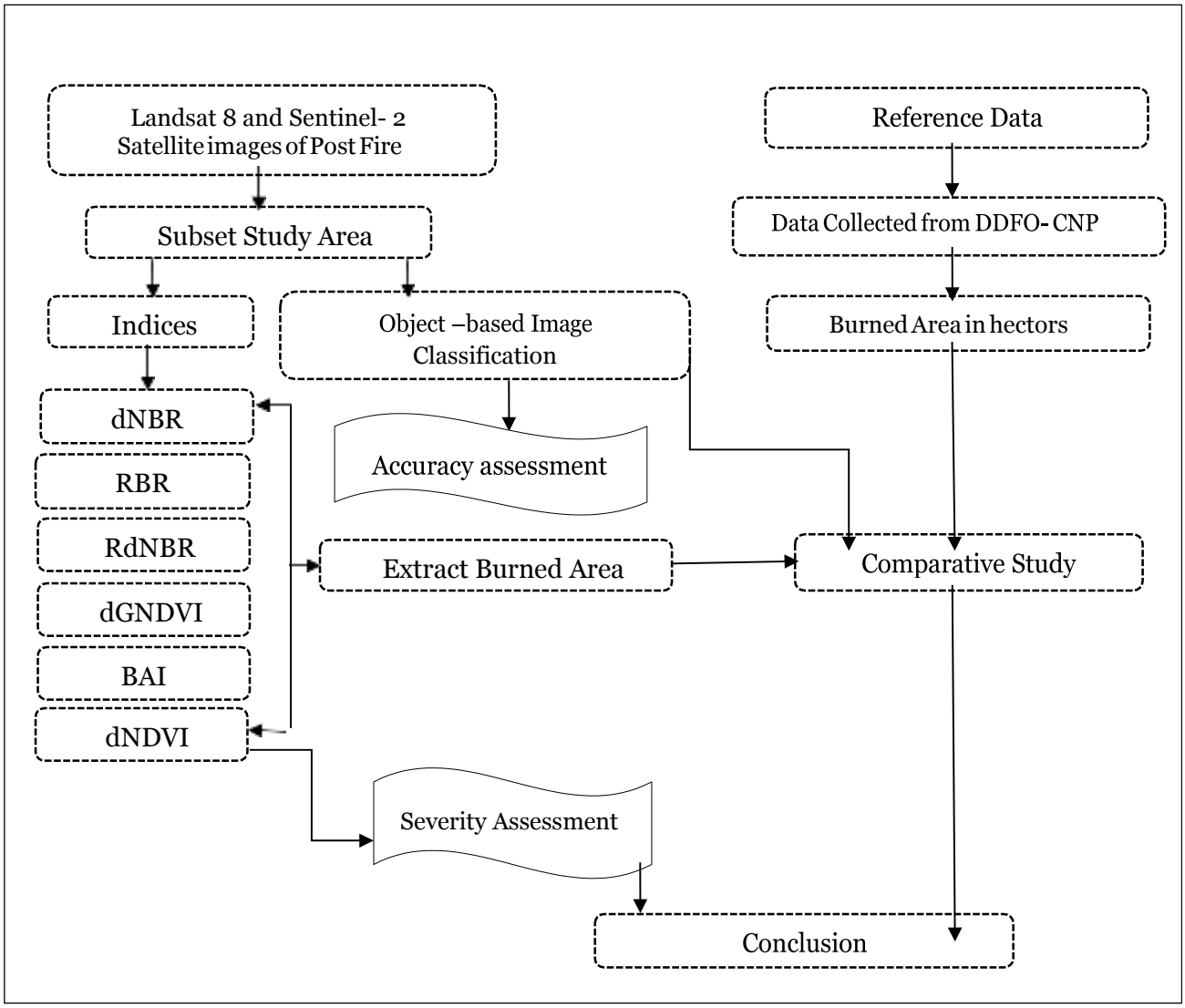

Figure 2: Research Methodology

The near-infrared and red bands strongly reflect and absorb the vegetation respectively and were used to calculate the Normalized Difference Vegetation Index (NDVI). Higher values indicate dense vegetation cover. As a first stage, NDVI indices were generated on pre and post-fire dates. The dNDVI index was calculated by subtracting the post-fire NDVI index from the pre-fire NDVI index. The Normalized Burn Ratio (NBR) index is one of the most widely utilized remote sensing-based forest fire monitoring research indices. The NBR index was employed which had a value range of -1 to +1. The burnt region was determined using a Differenced Normalized Burn Ratio (dNBR) computed from pre and post-fire images NBR.

To evaluate spectral fluctuation, the Relative Differenced Normalized Burn Ratio (RdNBR) index was used which was computed from NBR of pre-fire satellite images and dNBR obtained from pre and post- fire images. Chuvieco et al[2] developed the Burn Area Index (BAI) by combining the red and near-infrared spectral domains. The index was used to identify burnt areas. The red band is replaced by green in the Green Normalized Difference Vegetation Index (GNDVI). Using the difference in GNDVI calculated from pre and post-fire images, the Differenced Green Normalized Difference Vegetation Index (dGNDVI) generated and identified the burnt region. Table 3 gives the details of used band combinations for all indices.

Post-fire changes were found with the help of object-based classification techniques for specified classes using satellite images from Sentinel-2 and Landsat-8. In this case, six classes were chosen: evergreen forest, deciduous forest, waterbody, scrub forest, scrubland and burnt area. For this process, eCognition software with a multi-resolution segmentation algorithm was used. The segmentation stage was completed with selected parameters of 10 for scale, 0.5 for compactness and 0.1 for shape. For the accuracy assessment of both classified images, 50 random points were taken separately from the classified images and the user accuracy (UA), producer accuracy (PA) and Kappa values were determined. The accuracy was assessed with the following formulas:

$$\text{Overall Accuracy} = \frac{\text{Total Number of correct sample}}{\text{Total number of samples}} \times 100 \quad (1)$$

$$\text{Kappa Coefficient (T)} = \frac{(TS \times TCS) - \sum(\text{Colum total} \times \text{Row total})}{TS^2 - \sum(\text{Colum total} \times \text{Row total})} \quad (2)$$

where TS is the total number of samples and TCS is total corrected samples.

Table 3
Description of indices using Sentinel-2 and Landsat-8 satellite images

Name of Indices	Landsat -8	Sentinel-2
Normalized Burn Ratio **(**NBR)	$\frac{B5-B7}{B5+B7}$	$\frac{B8-B12}{B8+B12}$
Differenced Normalized Burn Ratio dNBR)	NBR pre-fire- NBR post-fire	NBR pre-fire- NBR post-fire
Relative Differenced Normalized Burn Ratio **(**RdNBR)	$\frac{dNBR}{\sqrt{(NBR\ pre-fire/1000)}}$	$\frac{dNBR}{\sqrt{(NBR\ pre-fire/1000)}}$
Normalized Difference Vegetation Index (NDVI)	$\frac{B5-B4}{B5+B4}$	$\frac{B8-B4}{B8+B4}$
Differenced Normalized Difference Vegetation Index (dNDVI)	NDVI pre-fire- NDVI post-fire	NDVI pre-fire- NDVI post-fire
Green Normalized Difference Vegetation Index (GNDVI)	$\frac{B5-B3}{B5+B3}$	$\frac{B8-B3}{B8+B3}$
Burn Area Index **(**BAI)	$\frac{1}{(0.1-B4)^2+(0.06-B5)^2}$	$\frac{1}{(0.1-B4)^2+(0.06-B8)^2}$
Differenced Green Normalized Difference Vegetation Index (dGNDVI)	GNDVI pre-fire- GNDVI post-fire	GNDVI pre-fire- GNDVI post-fire

Results and Discussion

In the study area, a fire occurred in the morning at 11.30 on March 15, 2017 and it was under control at 7.15 pm on the same day. As a result of the fire, 194 hectares of the scrub forest were destroyed as per DDFO-CNP. Satellite images from the Landsat-8 satellite before the fire on March 12, 2017, after the fire on March 28, 2017 and satellite images from the Sentinel-2 satellite before the fire on March 1, 2017, after the fire on March 21, 2017, were used to calculate the burnt area after the fire event. Figure 3 and figure 4 show the Landsat-8 and Sentinel-2 satellite images of the study region after the fire.

Indices: The burnt area is visible in both post-fire satellite images. By using threshold values, the changed fire area and no-change classes were determined in each index and the images were transformed into binary images. When compared the burnt area as determined by DDFO-CNP, the results showed that dNDVI and RdNBR offered superior outcomes to the other indices. These two indices which use Sentinel-2 and Landsat-8 to distinguish fire area, are shown in fig. 5. The burnt region seems brighter than the rest of the image in all indices. In sentinel-2 and Landsat 8 images, the dNDVI index gives a better result which is 212.27 and 224.88 ha respectively. Although the actual burn area is 194 ha, these estimates are exceptionally near to the reference value.

Reference data (Data from DDFO- CNP): After performing a comparison analysis, research summarized that the dNDVI and RdNBR indexes were the most accurate out of the six with a difference of only 18.27 and 30.88 hectares respectively. Table 4 shows the statistical difference between the derived indexes and object-based classification results with fire areas from the Department of Divisional Forest Officer-Chandoli National Park data.

Accuracy Assessment: Sentinel-2 and Landsat-8 images were used in the object-based classification of post-fire. By following the segmentation, six classes were identified: burnt area, evergreen forest, deciduous forest, scrubland, scrub forest and water body. User accuracy, producer accuracy and Kappa statistics were used to measure the accuracy of the classified images. Sentinel-2 image has 84% overall accuracy and 0.795 Kappa value whereas Landsat-8 image had 82 % overall accuracy and 0.765 Kappa value according to OBIA data (Table 5).

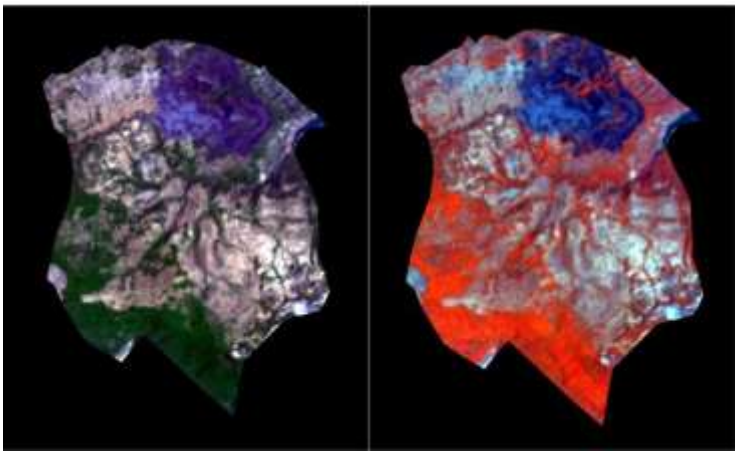

Figure 3: Landsat-8 satellite image of the study area after the fire a. True colour (B4, B3, B2), b) False-colour (B5, B3, B2)

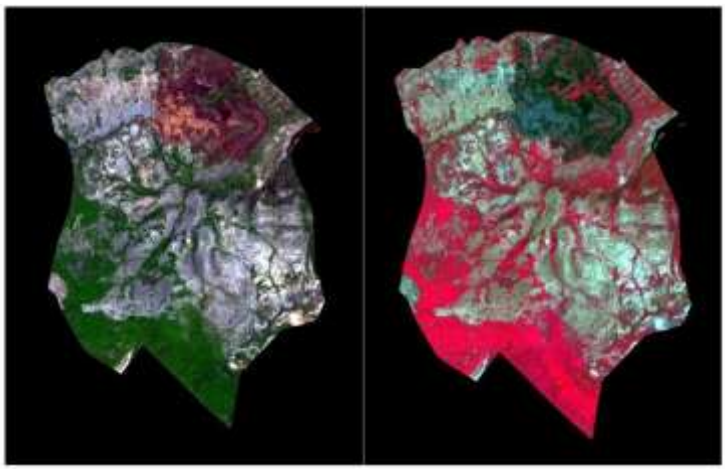

Figure 4: Sentinel-2 satellite image of the study area after the fire a) True colour (B4, B3, B2), b) False-colour (B8, B3, B2)

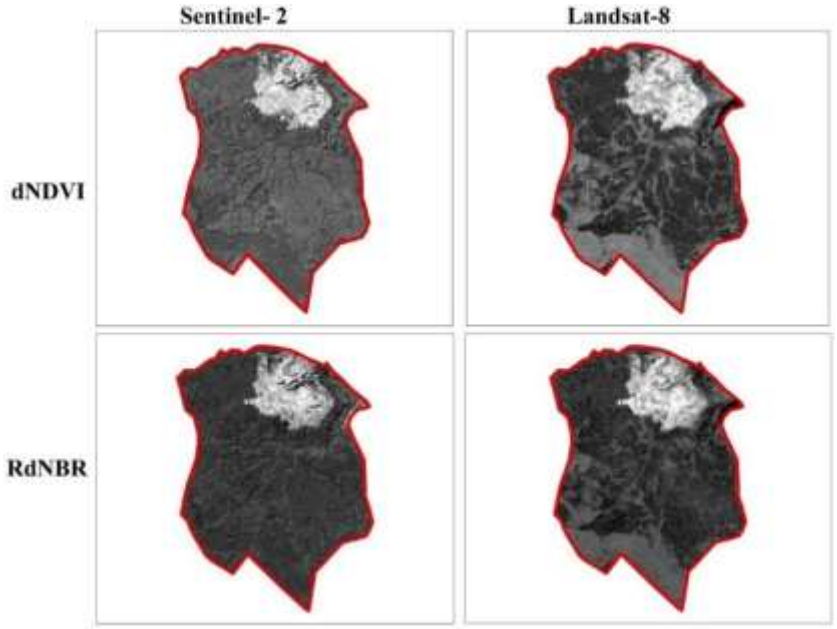

Figure 5: RdNBR and dNDVI results of Sentinel-2 and Landsat-8

Table 4
Forest fire areas (in hectors) obtained from indices and OBIA

Index	Sentinel-2	Difference from DDFO-CNP data	Landsat-8	Difference from DDFO-CNP data
dNBR	221.96	27.96	248.40	54.4
RBR	1.36	192.64	5.22	188.78
RdNBR	168.45	25.55	235.32	41.32
dNDVI	212.27	18.27	224.88	30.88
dGNDVI	224.23	30.23	249.87	55.87
BAI	259.66	65.66	258.06	64.06
Object-based	210.33	16.33	253.60	59.60

Table 5
Accuracy assessment of OBIA

Classes	Landsat-8 (%)			Sentinel-2 (%)		
	PA (%)	UA (%)	Kappa	PA (%)	UA (%)	Kappa
Evergreen Forest	87.5%	77.77%	0.814	77.77%	87.5%	0.835
Deciduous Forest	66.66%	75%	0.814	69.23%	90%	0.831
Scrub Forest	50%	75%	0.818	75%	75%	0.838
Scrub Land	89.47%	89.47%	0.789	93.33%	77.77%	0.821
Burned Area	100%	85.71%	0.817	100%	87.5%	0.836
Water Body	100%	66.66%	0.819	100%	100%	0.839
Overall Accuracy	**82%**			**84%**		
Kappa	**0.765**			**0.795**		

Table 6
Forest Fire Severity Analysis by using dNDVI index (Area in Ha)

Severity Class	Landsat-8	Sentinel- 2
Low	55.27	37.04
Moderate Low	67.25	68.83
Moderate High	68.56	77.68
High	33.80	28.72

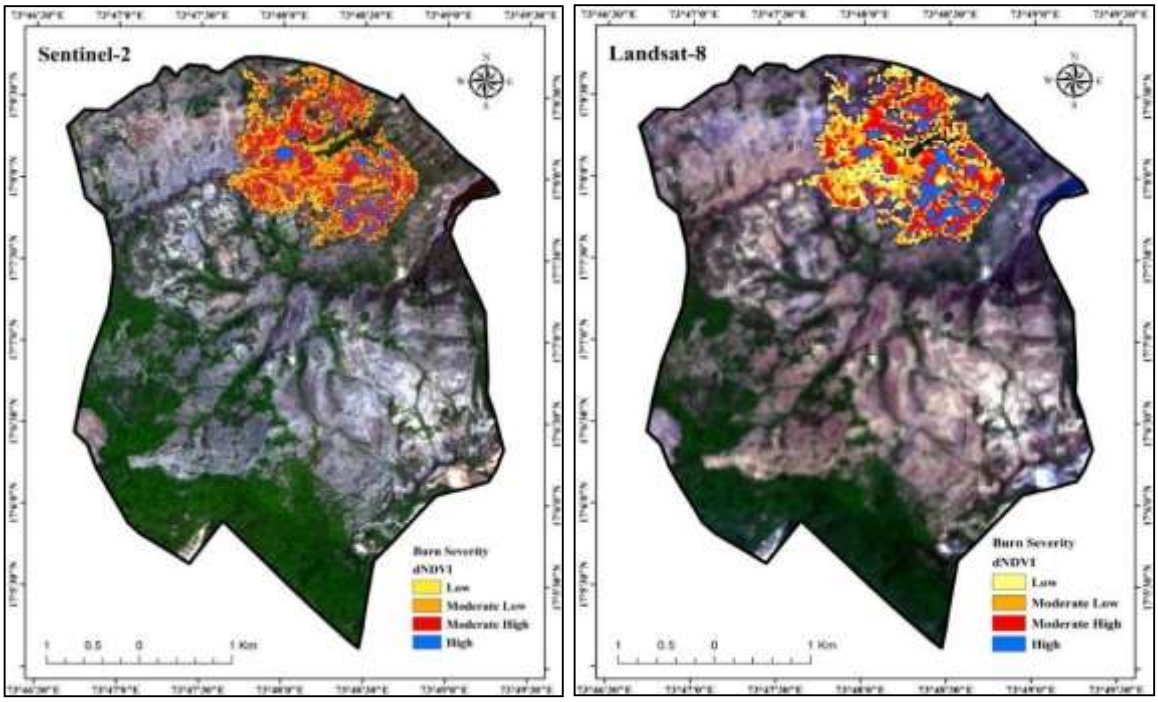

Figure 6: Severity Analysis using dNDVI of Sentinel-2 and Landsat-8

Fire Severity Analysis: The severity analysis defined four categories based on threshold values and the high findings were obtained in both cases by the dNDVI index (Fig. 6). According to the intensity maps, the fire had a high burning intensity in Sentinel-2 retrieved as moderate-high intensity in Landsat-8. The intensity of forest fires is shown in table 6 by class from low to high.

Conclusion

The significance of remote sensing technology in forest fire mapping, assessment and identification is highlighted in the present study. Instead of expensive and time-consuming land works, it was evaluated with new technology and the results of certain precision and accuracy in a far more cost-effective, quick and risk-free manner. The study aims to contribute to future studies by utilizing various indexes, algorithms, satellite technologies and bands. The study examined fire indices and object-based classification results through satellite images to determine fire extent and severity in the Nivale (Kolhapur) beat of Chandoli National Park of Maharashtra. The classified Sentinel-2 image had the highest accuracy when all applied indices were considered. It is also important to note that RdNBR is the second best index whereas the BAI had worst result.

After image categorization, dNDVI yielded the accurate value in the Sentinel-2 data. The Sentinel-2 satellite image is designed to have a greater spatial resolution than the Landsat-8 satellite image, so the object-based classification offers higher accuracy results. The burnt areas were overestimated during the categorization procedure in the Landsat-8 satellite image with greater pixel size. This is due to the large pixel size which causes it to categorize a pixel as burnt even if it is not completely burnt. It is a suitable method for quick mapping because it immediately detects the burnt area and intensity. Finally, the study concluded that the dNDVI index of post fire sentinel-2 satellite images could help in forest fire monitoring and management.

Acknowledgement

The authors are grateful to the Department of Divisional Forest Officer- Chandoli National Park at Karad affiliated with Sahyadri Tiger Reserve Management System for providing forest fire information within the study area as well as to the European Space Agency's (ESA) Research and Service Support team and to the United States Geological Survey (USGS) for providing Sentinel-2 and Landsat-8 imagery.

References

1. Aricak B., Enez K. and Küçük Ö., Determining Fire Potential by Using Satellite Images, *KSU J. Engineering Sci*., **Special issue**, 220-225 **(2012)**

2. Chuvieco E.P.A. and Martin M.P., Assessment of different spectral indices in the red-near-infrared spectral domain for burned land discrimination, *International Journal of remote sensing*, http://dx.doi.org/10.1080/01431160210153129, 37–41 **(2010)**

3. Delen A., Abdikan S., Sanli F.B., Bektas Balcik F. and Goksel C., Object Based Flooding Extent Mapping with Sentinel-2 Data, 9th International Symposium on Atmospheric Sciences (ATMOS), 705–712 **(2019)**

4. Ekwal Imam, Use of geospatial technology in evaluating landscape cover type changes in Chandoli National Park, India, *Comput. Ecol. Softw*, **1(2)**, 95–111 **(2011)**

5. Escuin S., Navarro R. and Fernández P., Fire severity assessment by using NBR (Normalized Burn Ratio) and NDVI

(Normalized Difference Vegetation Index) derived from LANDSAT TM/ETM images, *Int. J. Remote Sens.*, **29(4)**, 1053–1073, doi: 10.1080/01431160701281072 **(2008)**

6. Kurnaz B. and Bayik C. and Abdikan S., Forest Fire Area Detection by Using Landsat-8 and Sentinel- 2 Satellite Images: A Case Study in Mugla, Turkey, *Research Square*, DOI:10.21203/rs.3.rs-26787/v1 **(2020)**

7. Miller J.D. and Thode A.E., Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR), *Remote Sens. Environ.*, **109(1)**, 66– 80, doi: 10.1016/j.rse.2006.12.006 **(2007)**

8. Quintano C., Fernández-Manso A. and Fernández-Manso O., Combination of Landsat and Sentinel-2 MSI data for initial assessing of burn severity, *Int. J. Appl. Earth Obs. Geoinf*, **64**, 221–225, doi: 10.1016/j.jag.2017.09.014 **(2018)**

9. Tucker C.J., Red and photographic infrared linear combinations for monitoring vegetation, *Remote Sensing of Environment*, **8(2)**, 127–150, https://doi.org/10.1016/0034-4257(79)90013-0 **(1979)**.

(Received 08th September 2021, accepted 05th November 2021)