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Severity Classification of the Forest Fired Area by Utilizing Remote Sensing and GIS: A Case Study in Ella Sri Lanka

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Abstract— The burning of forest areas in Sri Lanka can be considered as one of the foremost issues that should be addressed. Human influence could be identified as the major cause of forest fires in Sri Lanka. Hence, identification, mapping, and taking necessary actions for forest fires are vital in the current context. The forest fire that occurred in the Ella area in 2019 was the focus of the case study. First, the burned location identification was the crucial part of the study due to the unavailability of a proper database of forest fires in Sri Lanka. Hence, with the use of newspaper articles and reports, the forest-fire area was identified at the beginning. Then by utilizing Sentinel-2 satellite images through the Normalized Burn Ratio (NBR) forest fire area was identified. Further, with occupying the difference of NBR (dNBR) mapped the severity of the fire by following the United States Geological Survey (USGS) fire classification scheme. The analysis was performed in Quantum GIS (QGIS) open-source software platform since the Semi-automatic Classification Plugin (SCP) provided the best framework for analysis. Even if immediate satellite images just after the incident were not present, mainly due to the cloud coverage, the analysis was able to obtain a considerable output. Consequently, owing to the study, 73.82 hectares of areas were identified as burned due to the wildfire and 15.65% of the area was highlighted as a high severity of the burn. In conclusion, the applied methodology could be used by any organization for forest scare mapping, and it is vital in future planning.

Keywords: *dNBR, forest fire, GIS, NBR, QGIS, remote sensing*

I. INTRODUCTION

Forest systems far could be considered as the heart of the ecosystem (United Nations, 2010) and provide invaluable service to nature. Hence, conservation of the forest areas is the accountability of all human beings subsequently we are all part of it. Deforestation, forest degradation, and forest fires might be identified as the biggest threat to the forest worldwide. In the fire ecology, burn severity is well-defined by the influence of fire on an environment (Peek, 1997). Thus, frequently occurring forest fires were the foremost environmental hazard in any ecosystem (Bajocco *et al.*, 2012; Erten and Musaoglu, 2018) mainly due to human influences (Gigović *et al.*, 2018). Hence taking necessary actions for the prevention is vital and could be identified as the major requirement in ecosystem conservation. Sri Lanka is a tropical island nation embraced with monsoon climate and the driving factors of the climate were wind and precipitation (Yamane, 2009). As per the evidence that is available (The Consortium of Humanitarian Agencies, 2016) approximately, two hundred forest fires occur annually contingent on the current weather conditions. Further, the fire hazards were often not in native forest areas and most of them were recorded in peak vegetation and woodlands of the south and central highlands (Series, 2009) and the study focused to investigate the forest fire occurred at Ella area in 2019.

Remote sensing usually defines as the remote monitoring features on the ground being without contact with it (Navalgund, Jayaraman and Roy, 2007). It is vital in the environmental-related analysis and hazard monitoring due to the spatial and temporal resolution characteristics and owing to the capability of monitoring remotely. The freely available satellite data integrate with open-source software platforms provide a better framework

for the experimental assessment (Van Westen, 2000). Freely available Multispectral (MS) Sentinel-2 satellites, at the medium-high spatial resolution, allow the advance of more detailed wildfire mapping (Filipponi, 2019). Sentinel-2 images were employed under investigation through the semi-automatic classification plugin (SCP) (Congedo, 2016) in Quantum Geographic Information System (QGIS). QGIS is a free and Open-Source Desktop GIS platform that permits map creation, edit, spatial analysis which is established on the Geographical Information Science (GIS) (Baghdadi, 2018). Further, the SCP plays a significant role in applied remote sensing analysis such as image downloading, preprocessing, classification, postprocessing, raster calculation etc.

Recognizing post-fire data is essential for post-fire administration activities and rehabilitation treatments. Hence, the main objective of the study is to map and quantify the burned area and demarcate the levels of burn severity. Further, the specific objectives express as follows.

- To identify the burned area by the forest fire
- To demarcate the fired area by using remote sensing techniques
- To map the level of severity of the fired area
- To quantify the correlation between NDVI, NBR, and dNDVI, dNBR.

Pre and post images are often used to distinguish the changes in every condition (Miller and Thode, 2018). Thus, pre-, and post-Sentinel-2 satellite images of the forest fire of the study area were implemented. Vegetation indices (Hayes and Sader, 2001) have been exposed to enhance detection of vegetation types, levels, etc., and further, ratio-based vegetation indices as well minimizing the topographic and atmospheric effects (Hayes and Sader, 2001).

II. METHODOLOGY

A. Study Area

Ella (6.8667° N, 81.0466° E) is a small town in the Badulla District. The Ella rock fire started on August 22nd and continued up to August 25th of 2019 as per the evidence from the news reported on the web since there is no proper forest fire database to access in Sri Lanka. Hence, identifying the correct location of the wildfire is one of the major concerns of the study.

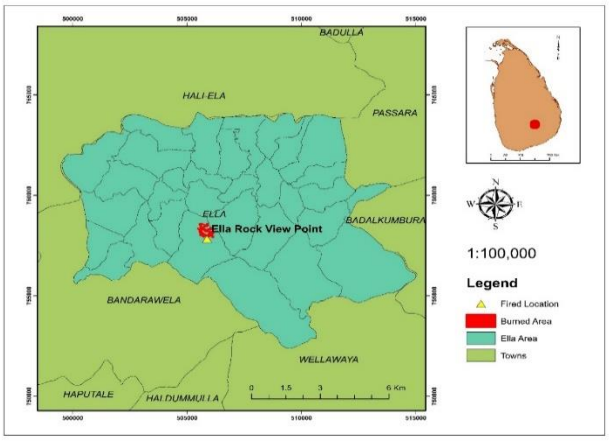

Figure 2: Study Area

B. Data

Sentinel 2 images downloaded from the Copernicus Sentinel Scientific data hub were utilized. The Pre and post Sentinel-2 images that were captured on 27th June 2019 and 10th September 2019 respectively were used since the incident occurred on 22nd August 2019.

C. Methodology Adopted

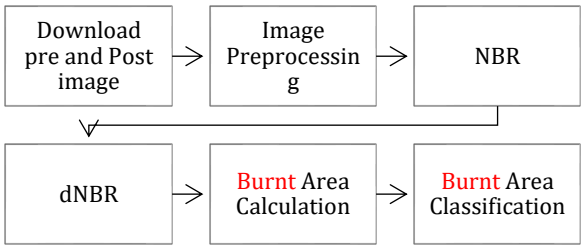

Figure 1: Methodology Adopted over the study

Google Earth images were used to identify the actual ground area by the forest fire subsequently it is difficult to find a database of the fire. Hence, news articles and reports regarding the forest fire were used as evidence. Then by using Google Earth, temporal images were identified the exact date and the location of the fire. The overall methodology implemented

over the investigation is stated in the above Figure.

D. Normalized Burn Ratio (NBR)

The raw Satellite image is compromised with a spectral band in spatial resolution and each spectral band has its way of interact with the features on the ground (Key and Benson, 2016) and the vegetation indices are defined based on the absorption and reflectance characteristic with the ground features and respective wavelength regions. The NBR has been developed to measure the burned areas efficiently by Key and Benson in 1996 (Key and Benson, 2016) and further, it's much similar to NDVI. NBR is a ratio-based vegetation index and can be stated as follows.

$$(\boldsymbol{NBR}) = (NIR - SWIR)/(NIR + SWIR)$$

Mostly, Mid Infrared upsurges from pre-fire to post-fire while the variation is utmost in extent related to other bands, and the discrepancy in between burns is greatest (Key and Benson, 2016). The ration-based indices benefit to remove within-scene topographic effects and between-scene solar illumination effects. This separates the actual reflective variances among the bands, which allows spatial and multitemporal assessment of the resulting NBR values efficiently. Change detection (Hayes and Sader, 2001) analysis is significant in measuring the changes that occurred due to particular incidence. Hence pre- and post-images are required to quantify the alteration. Consequently, to demarcate burned from unburned regions and to quantify the change that arises, the pre-and post-NBR images were subtracted. The delta NBR (ΔNBR) or dNBR (Key and Benson, 2016) can be stated as follows.

$$\boldsymbol{dNBR} = NBR_{Prefire} - NBR_{Postfire}$$

The pre-fire image contains high NIR values and low SWIR Digital Number (DN) values and further, the post-fire image contains low NIR values and high SWIR DN values comparatively. The levels of the burn severity were obtained by classifying the dNBR as per the United States Geological Survey (USGS) to decode the burn severity.

Table 1: Severity Level classification defined by the USGS Geological Survey

Severity Level	dNBR Range
Enhanced regrowth	–500 to –251
Enhanced regrowth	–250 to –101
Unburned	–100 to +99
Low severity	+100 to +269
Moderate-low	+270 to +439
Moderate-high	+440 to +659
High severity	+660 to +1300

III. RESULTS AND DISCUSSION

In the study area, nearly 73.82 hectares of area burned by the forest fire, and 63.92 % of the area was highlighted as burned severity while 15.65% of the area was highlighted as high severity as per the following Table 2

Table 1: Burned Area and the Percentage of coverage

Severity Level	Area in hectares	Percentage of Coverage
Enhanced regrowth high	00.07	00.06%
Enhanced regrowth low	00.12	00.10%
Unburned	41.49	35.92%
Low severity	36.12	31.27%
Moderate-low severity	19.63	17.00%
Moderate-high severity	18.04	15.62%
High severity	00.03	00.03%

The higher dNBR signifies more severe damage and regions with negative dNBR values imply improved efficiency after the fire (Key and Benson, 2016). The following Figure 03 illustrates the burn harshness level map of the study area. Due to the cloud cover and the unavailability of data, the post-fired image collected after two weeks from the fire happened nonetheless capable to obtain a sensible production.

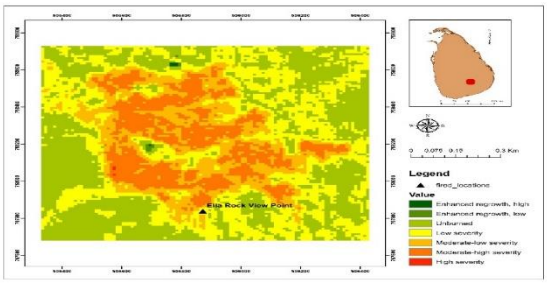

Figure 3: Burn severity classification of the Forest Fire

IV. CONCLUSION AND RECOMMENDATIONS

Remote sensing analysis plays a significant role in forest fire mapping and for better representation of the result required to integrate with the field measurements vital. Further, the freely available satellite images and the open-source platforms provide an excellent framework for scientific investigations. The NBR index was vital in forest fire mapping and recommends using in-field measurement when the physical approach gets disturbed or difficult. Even though the optical satellite images were providing better analysis, the cloud cover could be identified as a major drawback. Hence, integrated optical data with microwave data would be effective than a single type. As per the investigation, 73.82 ha were burned, and it is not a small value compared to our country.

Continuous measuring of the forest fires and maintaining a proper web-based fire management database are timely requirements of the country and it is better to change the manual bookkeeping to the database management system for storing and retrieving the forest-related data. That will help future forest management, policy development, awareness, and scientific instigations like predicting the future pattern of forest fire. Further, relevant authorities should take necessary actions to prevent forest fires since it is difficult to measure the damage that affects nature due to the forest fires.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

dNBR : difference of NBR

GIS : Geographic Information Sciences

NBR. : Normalized Burn Ratio

USGS : United States Geological Survey

QGIS : Quantum GIS

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