Wildfire in the Mourne Mountains

Remote Sensing Assessment of the 23rd–25th April 2021 Incident

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Introduction

Wildfires are increasingly recognized as a pressing global environmental challenge due to their effects on ecosystems, biodiversity, and climate systems (Chuvieco et al. 2019).
The Mourne Mountains, designated as an Area of Outstanding Natural Beauty (AONB), are home to critical ecosystems such as upland heathlands and peat bogs, which provide essential services like carbon sequestration and water regulation. However, recent wildfire events, including the devastating 2021 fire that burned 720 acres of sensitive habitats, have demonstrated the vulnerability of these landscapes and the urgent need for better wildfire monitoring and management tools (National Trust 2023; McDaid 2023). This research assesses the April 2021 wildfire using remote sensing techniques, satellite imagery, and analysis in the GIS program ArcGIS Pro.



Figure 1: Photograph taken from Newcastle on April 23, 2021, at 09:50



Figure 2: Photograph taken from the Blood Bridge parking on April 23, 2021, at 10:16

Objective:

- **Assess Burn Severity**: Quantify the severity of the 2021 wildfire in the Mourne Mountains using remote sensing indices (NBR and dNBR).
- **Evaluate Vegetation Stress and Recovery**: Use dNDVI, MSI, and time series analysis of NBR to monitor vegetation conditions, analyse moisture stress, track recovery trends, and classify areas based on resilience over time.

Local Fires:

As per McDaid (2023) the April 2021 wildfire (Figure 3) burned 720 acres (291 hectares) of upland heathlands and peat bogs, impacting areas crucial for carbon storage and water regulation. This followed the 2011 fires, which destroyed over 700 hectares of forests and water catchments, costing £8 million (Campbell 2021). Other fires, like the 2022 Annalong Valley fire (Campbell 2022) and the 2017 Silent Valley fire, highlight the region's vulnerability to fire damage.



Figure 3: Photograph taken close to Bloody Bridge Parking on April 23, 2021 at 10:25



Figure 4: Area of Interest (AOI)

Area of Interest:

The area of interest (AOI) where the fire occurred is situated on the slopes of Slieve Donard, the highest peak in Northern Ireland, located on the eastern side of the Mourne Mountains (Figure 4). This area faces the city of Newcastle (Figure 1) and is characterized by its steep terrain and proximity to sensitive ecosystems, making it both an ecologically significant and visually striking landscape (National Trust 2023). The fire was located between Glen River and Bloody Bridge trail. Firemen access the location from Bloody Bridge Carpark (Figure 2).

Methodology

Data collection:
For this study Sentinel-2 satellite was most suitable for the analysis of the wildfire in the Mourne. **Sentinel-2 is** a European Earth observation mission under the **Copernicus program**. Twin satellites phase 180° apart provides a 5-day revisit frequency at the equator and captures images across 13 spectral brands with spatial resolution of 10, 20 and 60 m over a 290 km orbital swath width (Sentinel-2 nd).

The datasets include satellite images selected to capture long-term pre-fire conditions, the active fire period, post-fire conditions, and long-term post-fire recovery (Table 1).

Table 1: Satellite datasets used in analysis

Satellite/Sensor-satellite platform	Company	Image Captured	Time taken	Resolution per pixel	Number of spectral bands
Sentinel-2A	Copernicus	15. 04. 2020	11:43:51	10 m	13
Sentinel-2B	Copernicus	22. 04. 2021	11:33:09	10 m	13
Sentinel-2B	Copernicus	25. 04. 2021	11:43:49	10 m	13
Sentinel-2A	Copernicus	27. 05. 2021	11:33:21	10 m	13
Sentinel-2B	Copernicus	20. 04. 2023	11:43:51	10 m	13

The workflow of analysis involved importing Sentinel-2 images into ERDAS for reprojection to the Irish grid and geometric correction, clipping to the area of interest (AOI), generating NDVI, NBR, and MSI indices, performing raster calculations and reclassification in ArcGIS Pro, followed by analysis and final image creation (Figure 5).

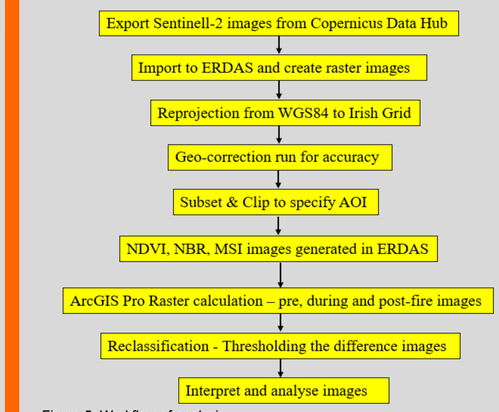

Figure 5: Workflow of analysis

Analysis used in the project and Indexes Calculations:

NDVI (Normalized Difference Vegetation Index)
Bands: Red (Band 4) and Near-Infrared (NIR, Band 8)
Formula: NDVI=NIR−Red / NIR+Red
Change Detection: calculation of difference images (dNDVI) by subtracting post-fire from pre-fire images using raster calculation:
Threshold for dNDVI: -1.0 to –0.3 vegetation regrowth, -0.3 to –0.1 minimal or no vegetation lost, -0.1 to 0.1 moderate vegetation lost, more than 0.1 severe vegetation lost (Walz and Weber nd)

MSI (Moisture Stress Index)
Bands: NIR (Band 8) and SWIR (Band 11)
Formula: MSI=SWIR / NIR
Threshold for MSI: -0.5 to 1.5 low stress, 1.5 to 2 moderate stress, 2 to 4 high stress (Sentinel Hub nd)

NBR (Normalized Burn Ratio)
Bands: NIR (Band 8) and Shortwave Infrared (SWIR, Band 12)
Formula: NBR=NIR−SWIR / NIR+SWIR
Threshold for NBR: -0.2 to 0 sparse vegetation (e.g. burned area), 0 to 0.3 moderate, 0.3 to 0.6 dense, 0.6 to1 very dense vegetation – e.g. unburn healthy area (DEA 2023)
Change Detection: calculation of difference images (dNBR) by subtracting post-fire from pre-fire images using raster calculation (J. Karl nd).
Threshold for dNBR: -0.5 to -0.1post-fire regrowth, -0.1 to 0.1 unburn, 0.1 to 0.3 low-severity burn, 0.3 – 0.45 moderate-severity burn, 0.45 -1 high-severity burn
Time series analysis: crate a time series of NBR images to track vegetation recovery over time, reclassify analysis used for it.

Results

Difference in Normalized Difference Vegetation Index (dNDVI)

Post-fire vegetation loss map, highlighting the spatial extent of vegetation loss following the wildfire based of difference in Normalized Difference Vegetation Index dNDVI (Figure 6).

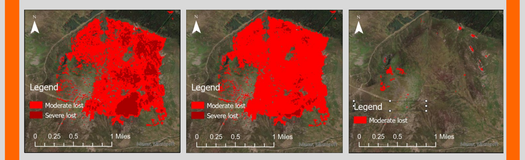

Figure 6: Vegetation loss maps at different time intervals post-fire. (A) Immediate post-fire vegetation loss (22 April 2021 - 25 April 2021) showing 222 hectares of moderate damage and 68 hectares of severe damage. (B) Short-term post-fire vegetation loss (22 April 2021 - 27 May 2021) showing 263 hectares of moderate damage and 4 hectares of severe damage. (C) Long-term vegetation loss (22 April 2021 - 20 April 2023) indicating 6 hectares of moderate damage persisting after two years.

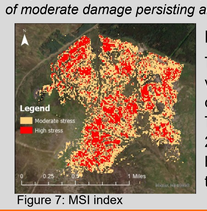

Figure 7: MSI index

Moisture Stress Index (MSI)

The Moisture Stress Index (MSI) provides key information about the moisture conditions in the affected area (Figure 7). The index on the day of the fire, April 25, 2021, shows moderate stress on 125 hectares, while high stress indicates intense burning on 70 hectares.

Temporal Analysis of Fire Impact and Vegetation recovery using Differential Normalized Burn Ratio dNBR (Figure 8 and Table 2)

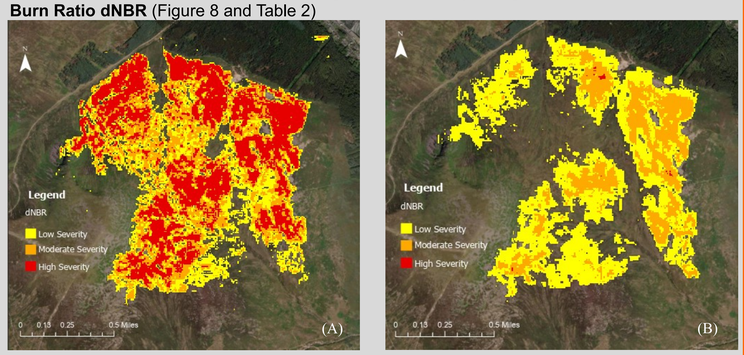

Figure 8 : Temporal analysis of fire impact and vegetation recovery using dNBR, showing (A) immediate fire effects (22 April 2021 - 25 April 2021) and (B) short-term post-fire conditions (22 April 2021 - 27 May 2021), where red indicates high severity and green represents minimal impact or recovery. Long-term recovery (22 April 2021 - 20 April 2023) showed close to zero burn (C).

Table 2: Summary of burn severity classes showing the area (in hectares) for each level, derived from dNBR analysis of the April 2021 wildfire event.

Areas in hectares → / Severity classes ↓	Immediate fire impact	Short-term post fire condition	Long-term recovery
Post-fire regrowth	119.99	273.18	96.9
Unburned	208.95	124.7	508
Low-severity burn	66.95	118.37	0.1
Moderate-severity burn	87.48	52.48	0
High-severity burn	103.24	0.35	0

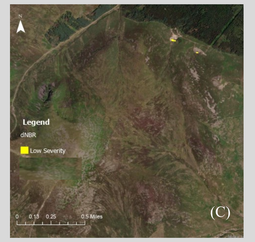

Figure 8: Long-term recovery (C)

Temporal Analysis of Vegetation Density Using Normalized Burn Ratio (NBR)

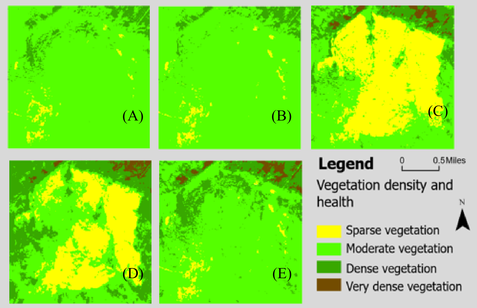

Figure 9: Map series using NBR index

The following map series (Figure 9) provides a visual representation of vegetation density changes over time, highlighting the impact and recovery stages of the wildfire.

Normalized Burn Ratio (NBR) index is used to analyse long-term pre-fire (A), pre-fire (B), during-fire (C), post-fire (D), and long-term post-fire (E) conditions.

This analysis clearly indicates areas with little to no green vegetation cover as well as recently burn areas (shown in yellow). Threshold of zero was set for this area.

The timeline analysis on the right side (Figure 10) quantifies vegetation density changes over different phases of the wildfire using Normalized Burn Ratio (NBR). X-axis represent NBR in the time of long-term pre-fire, pre-fire, during-fire, post-fire and long-term post-fire conditions and Y-axis represent areas in hectares (ha).

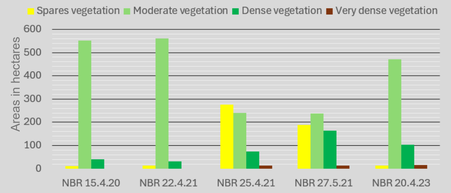

Figure 10: Timeline analysis (areas in ha per each analysed day)

Conclusion

In this study we examine fire impact on a small area using remote sensing indices such as dNDVI, dNBR, NBR and MSI. By analysing the April 2021 wildfire event, we identify 258 hectares immediately affected by fire with 103 ha severely burned and 87 moderate burned and 67 low-severity burned. Moisture Stress Index (MSI) on the day of fire indicated high MSI for 70 hectares, which indicates an intense burning and 125 hectares moderate moisture index stress. Two months after the fire was 171 hectares still affected but only 0.35 with high severity burn, 52 medium and 118 low. In two years after the fire index NBR shows nearly full recovery of the place. Vegetation within the square of AOI (not all affected by fire) increased from 329 ha to 398 ha two months after the fire to 605 in two years. This research underscores the importance of using satellite imagery in monitoring wildfire impact and assessing vegetation recovery over time.

Other Sources on the Mournes Wildfire



Figure 11: 23.4.2021 data from VIIRS—Suomi NPP (375 m) 3:57 and VIIRS - NOAA-20 (375m) 4:48



Figure 12: 24.4.2021 data from VIIRS—Suomi NPP (375 m) 15:09 and VIIRS - NOAA-20 (375m) 14:18 and MODIS - Terra 12:20 and Aqua 14:09

NASA's FIRMS provides near-real-time data on active fires around the world using thermal detection from satellites. FIRMS primarily utilizes data from the MODIS and VIIRS instruments on NASA's Terra and Aqua satellites, as well as the Suomi-NPP satellite, to identify hot spots that indicate potential fires (Figure 11 and 12).



PlanetScope is a satellite constellation operated by Planet Labs that captures high-resolution, multispectral imagery of Earth's surface and was the source clearly shows the burning landscape (Figure 13).

Scan the bar code to see PlanetScope Scene Story.

Figure 13: PlanetScope Scene: Satellite image from 24th April 2021 at 10:44:05 UTC, with 0% clouds and 3x3 meters per pixel.

References

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