Automated Burned Area Delineation from Satellite Imagery

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1. Introduction

Motivation:

- From 1971 to 2021 burned areas have increased 172%. NIDIS estimates a 3% to 52% increase in coming decades [1]
- Burned area delineation provides critical data about size of effected areas and severity. Historically data was collected by on the ground teams
- Sentinel-2 satellite imagery is widely available for use in burn quantification



Figure 1. Forest Fire [1]

Satellite Burned Area Dataset [2]:

- The dataset covers 73 total fires from 2017-2019 from locations across Europe. Pre and post-fire Sentinel-2 images, and ground truth masks generated using Copernicus Emergency Management System data per fire.
- Sample images from Madeira fire

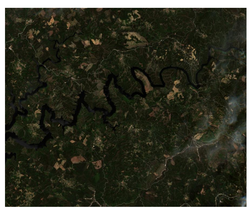


Figure 2A: Pre-Fire Sentinel-2



Figure 2B: Post-Fire Sentinel-2



Figure 2C: Ground Truth Mask

- Sentinel-2 bands include aerosol, blue, green, red, red edge, near infrared (NIR), narrow NIR, water vapor, and short-waver infrared (SWIR)

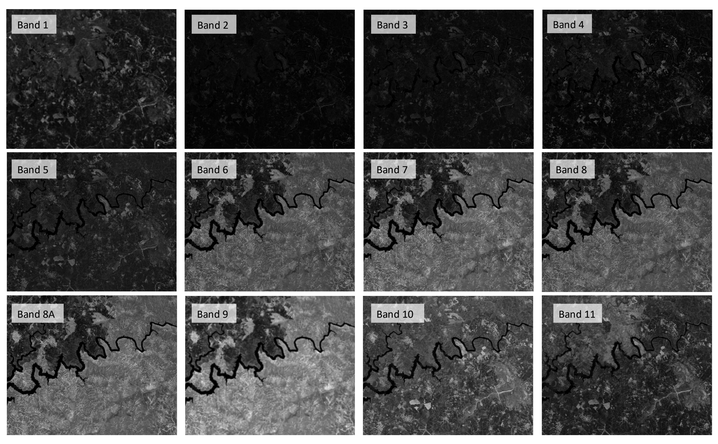


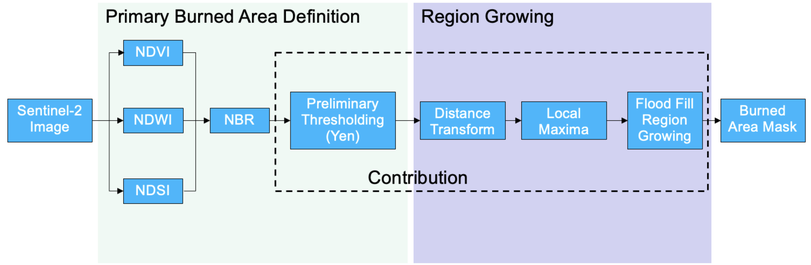
Figure 3: Sentinel-2 Bands

Band 1 – Aerosol (60m)	Band 7 – Red Edge (20m)
Band 2 – Blue (10m)	Band 8 – NIR (10m)
Band 3 – Green (10m)	Band 8A – Narrow NIR (20m)
Band 4 – Red (10m)	Band 9 – Water Vapor (60m)
Band 5 – Red Edge (20m)	Band 11 – SWIR (20m)
Band 6 – Red Edge (20m)	Band 12 – SWIR (20m)

2. Methods

Processing Pipeline:

- Extended from the segmentation model proposed in [3] by adding Yen method thresholding and flood filling from local maxima.



- Normalized Difference Vegetation Index = $NDVI = \frac{NIR-RED}{NIR+RED}$
- Normalized Difference Water Index = $NDWI = \frac{GREEN-NIR}{NIR+GREEN}$
- Normalized Difference Snow Index = $NDSI = \frac{GREEN-SWIR}{SWIR+GREEN}$
- Normalized Burn Ratio = $NBR = \frac{NIR-SWIR}{NIR+SWIR}$

Preliminary Burned Area Delineation:

- A mask is created to isolate water, snow, clouds, and live vegetation from burned area consideration. Sample images for the Madeira fire shown:



Figure 3: NDVI

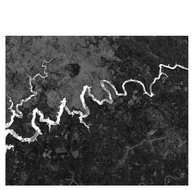


Figure 4: NDWI

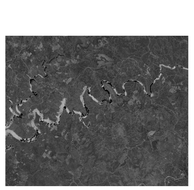


Figure 5: NDSI

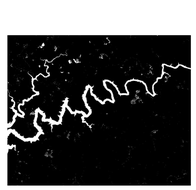


Figure 6: Total Mask

- Excluding masked portions, the NBR is then computed for the pre and postfire images. To extract the most probable burns, Yen thresholding [4] was utilized on the postfire image. See pre and post-fire NBR and histogram analysis for Madeira fire:



Figure 7: Pre-fire NBR

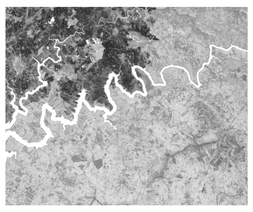


Figure 8: Post-fire NBR

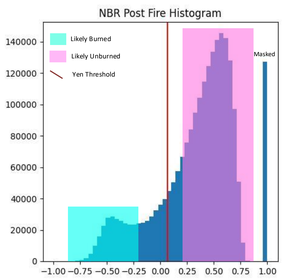


Figure 9: Yen Thresholding Analysis

Region Growing:

- From the thresholding results, the distance transform of the mask is taken, and the local maxima points are extracted. These local maxima then seed a tolerance-based flood fill to capture more of the low severity burn regions:

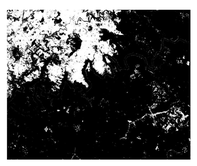


Figure 10: NBR Mask

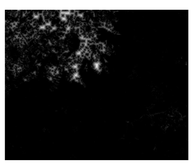


Figure 11: Distance Transform

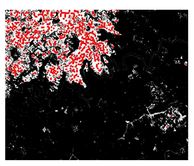


Figure 12: Local Maxima

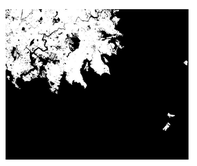


Figure 13: Flood Fill Results

3. Experimental Results

Sample Results:

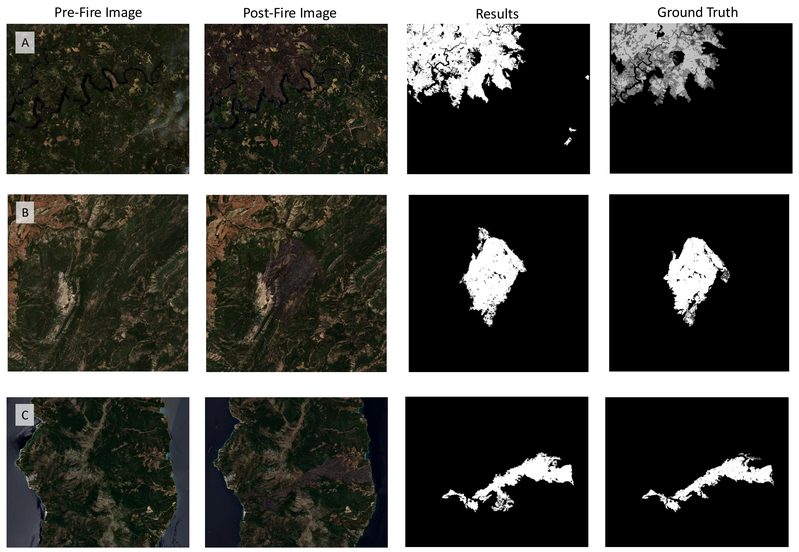


Figure 14: Pre and post-fire images, pipeline results, and ground truth images for the Madeira (A), Segura de la Sierra (B), and Ogliastro (C) fires respectively

Quantitative Results:

- For 32 fires
  - Average accuracy was 91%
  - Average recall was 77%
  - Average precision was 73%

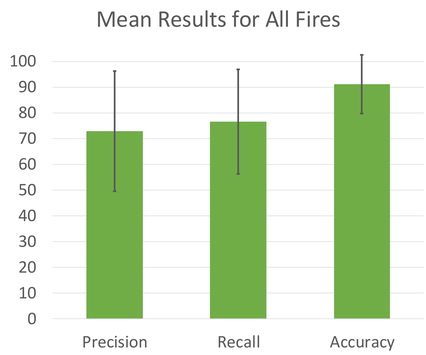


Figure 15: Mean precision, recall, and accuracy for all samples

* Note – Ground truth results were broken up by severity category. Category designation was not evaluated in this experiment.

4. Conclusion and Future Work

- Pipeline was robust against different types of bodies of water, regional variation, and clouds
- Performed moderately for small, widespread, patches of burned area
- Difficulty identifying areas of low burn severity

Next Steps:

- Analyze the effects of seasonal changes on refraction indices
- Incorporate severity class labeling
- Quantify burn areas in terms of surface area (square kilometers)

References:

- [1] NOAA, "Study Finds Climate Change to Blame For Record-Breaking California Wildfires," National Integrated Drought Information System, 8 August 2023. [Online]. Available: https://www.drought.gov/news/study-finds-climate-change-blame-record-breaking-california-wildfires-2023-08- 08#:~:text=It%20is%20estimated%20that%20from, from%203%25%20to%2052%25.. [Accessed 2023].
- [2] L. Colomba, A. Farasin, S. Monaco, S. Greco, P. Garza, D. Apiletti, E. Baralis and T. Cerquitelli, "A Dataset for Burned Area Delineation and Severity Estimation from Satellite Imagery," in 31st ACM International Conference on Information and Knowledge Management, 2022.
- [3] M. Sismanis, R.-T. Chadoulis, I. Manakos and A. Drosou, "An Unsupervised Burned Area Mapping Approach Using Sentinel-2 Images," Land, vol. 12, no. 379, 2023.
- [4] J.-C. Yen, F.-J. Chang and S. Chang, "A New Criterion for Automatic Multilevel Thresholding," *IEEE Transactions on Image Processing*, vol. 4, no. 3, 1995.