



Deep Neural Networks for Global Wildfire Spread Prediction

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Wissen für Morgen

Introduction & Motivation

- Increase in wildfire events: extensive environmental, humanitarian, and economical damages
- Crucial knowledge for forest and park managers to estimate possible losses
- Use multi-temporal satellite imagery to predict forest fire spread in order to prevent damages caused by wildfires
- No currently existing dataset or approach to complete this task, must build own dataset



Image: Fires in Southern Europe in 2017

Overview of Thesis Goal

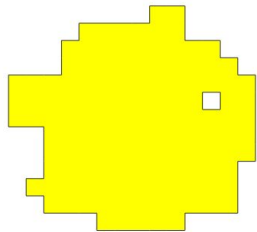
Research Questions:

- Can wildfire burn masks with low resolution, collected from multiple sources, be leveraged to build a world-scale dataset for spatiotemporal fire prediction?

Implementation:

- Create a global burn mask dataset that can be used for spatiotemporal fire prediction

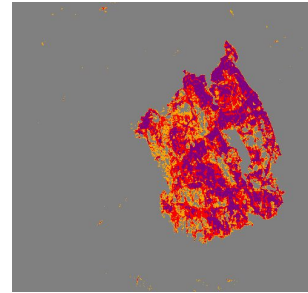
Overview of Global Wildfire Database Process



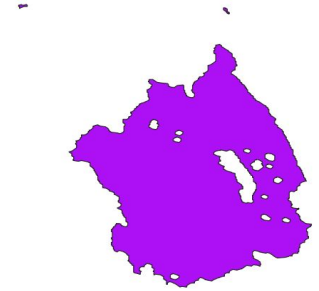
GlobFire Shp
500m



Sentinel-2 L2A
Imagery



Burn Indices



UniFireS Shp
10m

Data Sources

Satellite Imagery: Sentinel Hub

- Optical Imagery from Sentinel-2

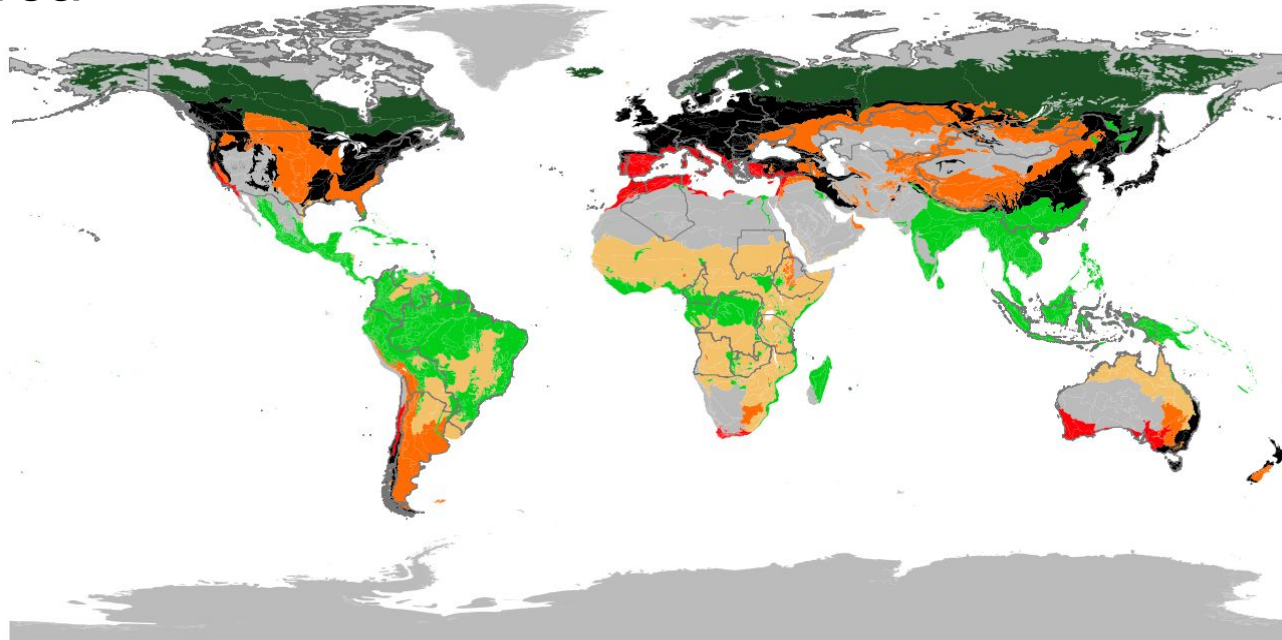
Burn AOI: Global Wildfire Information System (GWIS) - GlobFire (500m)

Burn Mask Methodology: European Forest Fire Information System (EFFIS)



Study Area

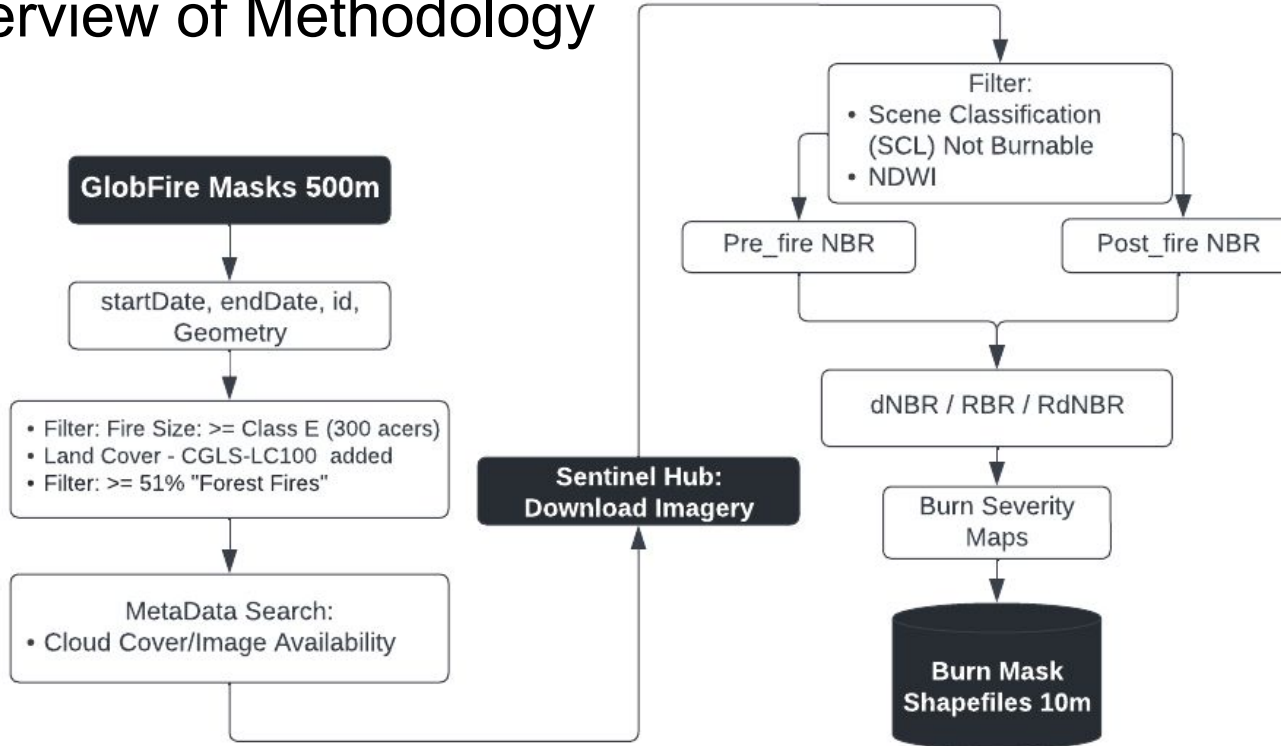
Countries Selected by Biome



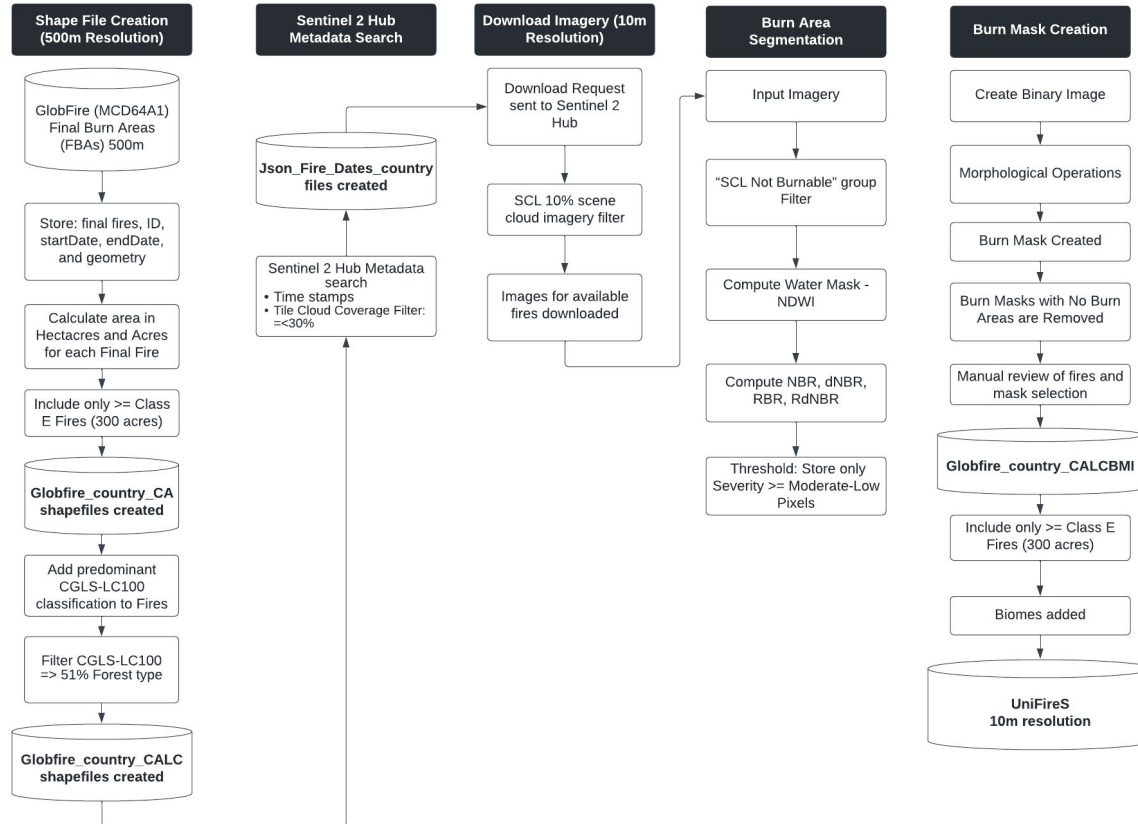
Legend

- | | | |
|--------------------------------|---------------------------------|----------------|
| Selected Countries | Temperate Grasslands & Savannas | Boreal Forests |
| Tropical Forest | Temperate Forest | Others |
| Tropical & Subtropical Savanna | Mediterranean Forests | |

Quick Overview of Methodology



Overview of Methodology



Fire Selection Criteria - Temporal

- Spatial: pre-selected countries
- Temporal: 2018-2020
- Temporal Filter: 6 images
 - ≤ 120 before endDate and 40 days after endDate
 - Mask creation: code utilizes pre_fire_0 and post_fire

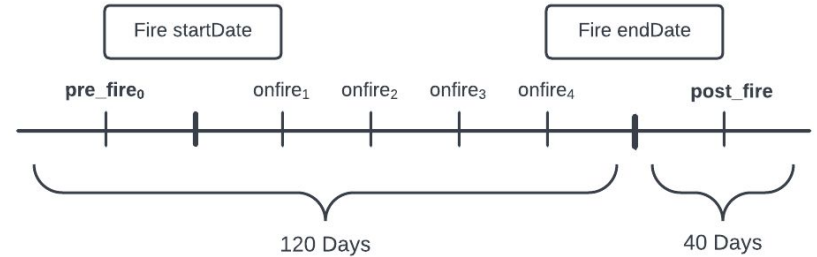


Figure 1: Ideal scenario

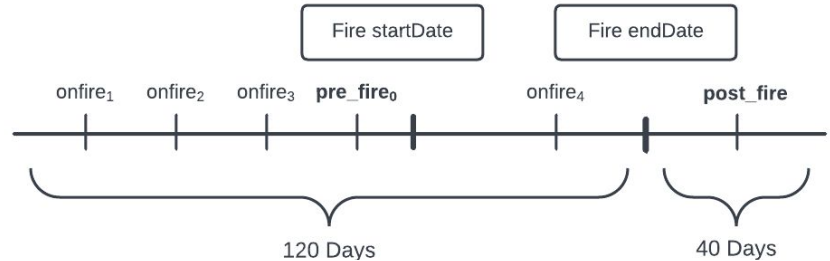


Figure 2: Minimum requirement scenario

Fire Selection Criteria - Fire Size & Land Cover

- Fire Size: \geq Class E Fire (300a = 124ha)
- Land Cover Filter
 - Copernicus Global Land Service: Land Cover 100m (CGLS-LC100) Product [6]
 - \geq 51% “forest” land covers

LEVEL 3						
value map	grouping	group code	R	G	B	class name
0		0	40	40	40	unknown (no input data available)
111		111	88	72	31	closed forest, needle-leaved, evergreen
113		112	102	62		closed forest, needle-leaved, deciduous
112		112	0	153	0	closed forest, broadleaved, evergreen
114		114	0	204	0	closed forest, broadleaved, deciduous
115		115	78	117	31	closed forest, mixed type
116		116	0	153	0	closed forest, unknown type
121		121	102	88	0	open forest, needle-leaved, evergreen
123		123	141	118	0	open forest, needle-leaved, deciduous
122		122	141	180	0	open forest, broadleaved, evergreen
124		124	160	220	0	open forest, broadleaved, deciduous
125		125	146	153	0	open forest, mixed type
126		126	100	140	0	open forest, unknown type
20		20	255	187	34	shrubland
30		30	255	255	76	herbaceous vegetation
90		90	0	150	160	herbaceous wetland
100		100	250	230	160	moss & lichen
60		60	160	180	180	bare / sparse vegetation
40		40	240	150	255	cropland
50		50	250	0	0	built-up
70		70	240	240	240	snow & ice
80		80	0	0	255	permanent inland water bodies
200		200	0	0	128	sea

Image 1: Land Cover Classes

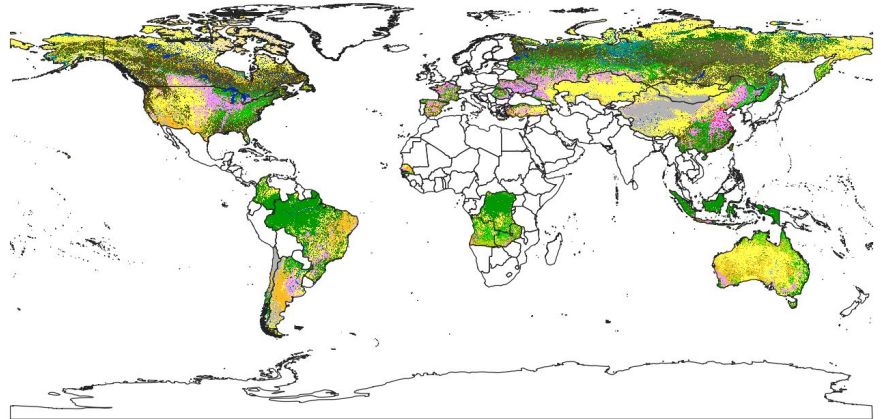
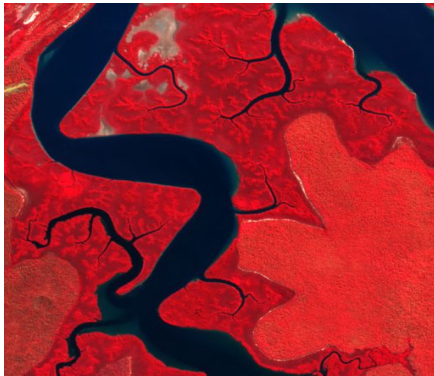


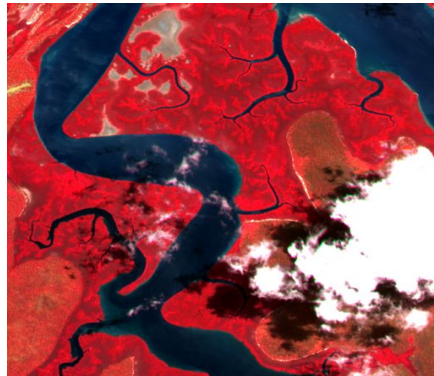
Image 2: Study Areas with Land Cover [6]

Fire Selection Criteria - Cloud Coverage

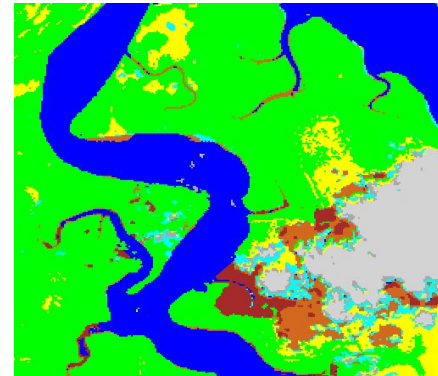
- Cloud coverage tile: $\leq 30\%$
- Cloud coverage scene: $\leq 10\%$
- Pixel Availability scene: $\leq 30\%$



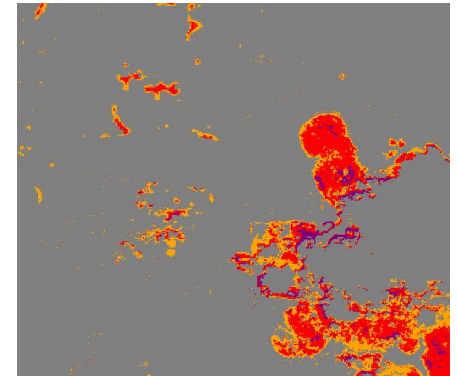
Pre Fire False Image
Id: 22646734



Post Fire False Image
Id: 22646734



SCL
Id: 22646734



dNBR Burn Severity
Id: 22646734

Images: Example of the **importance** of cloud coverage to the burn index

Review of Fire Filtering Process

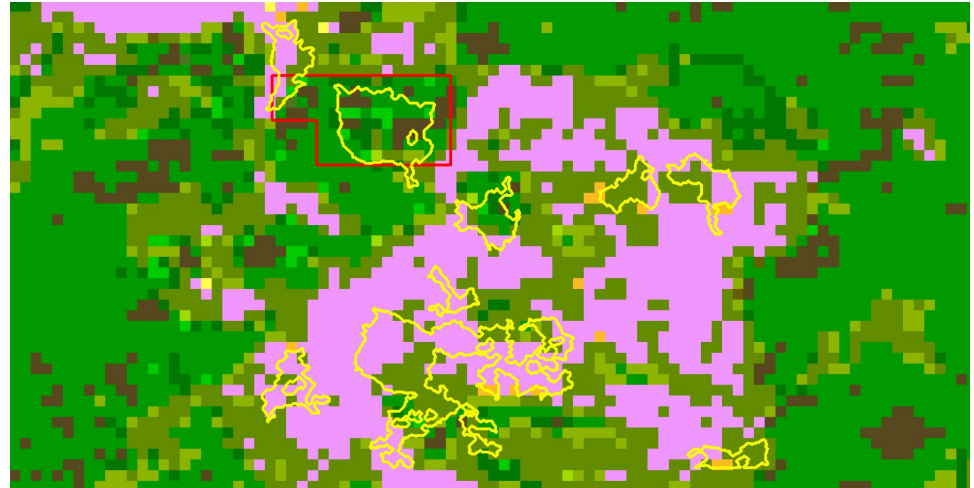
Biome Type	CA Total	CALC Total	Downloaded Total	CALCBMI Total	CALCBMIB Total
Boreal Forests	157,099	8,483	1,310	541	504
Mediterranean Forests	84,470	18,967	1,060	406	401
Temperate Forest	96,607	2,224	991	446	393
Temperate Grasslands & Savannas	90,543	1,650	772	300	252
Tropical & Subtropic Savanna	992,265	134,670	6,766	1,984	1,978
Tropical Forest	194,739	1,644	1,780	571	553
Grand Total	1,615,723	178,638	12,679	4,248	4,081

Table 9.2 Comparison of available fires per biome through the filtering process.




Manual Filtering

- Completed a second review of fire masks in order to ensure only “Very Good” burn masks were within the set
- Removed smaller fire sizes (< Class E)
- Re-ran the land cover classification to remove fires that were re-classified as predominantly agriculture

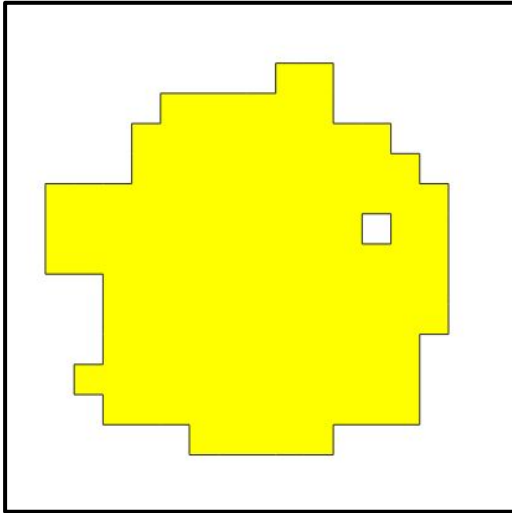
Post-Processing Agricultural Fire



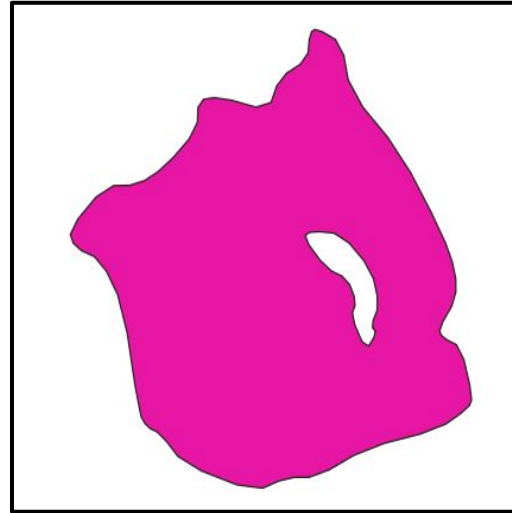
Legend

- | | |
|---|---|
|  CALCBMIB Id: 23164189 | Land Cover Class |
|  GlobFire Id: 23164189 |  40 - Cultivated and managed vegetation/agriculture (cropland) |

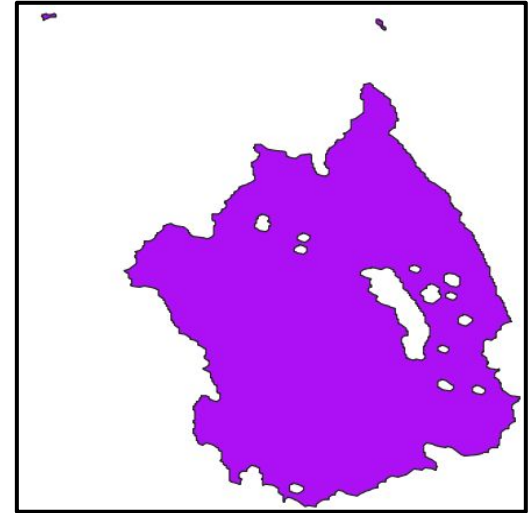
Comparison GlobFire, EFFIS, & Thesis dNBR.Shp



GlobFire Shp
(ID: 23749235)



EFFIS Shp
(ID: 23749235)



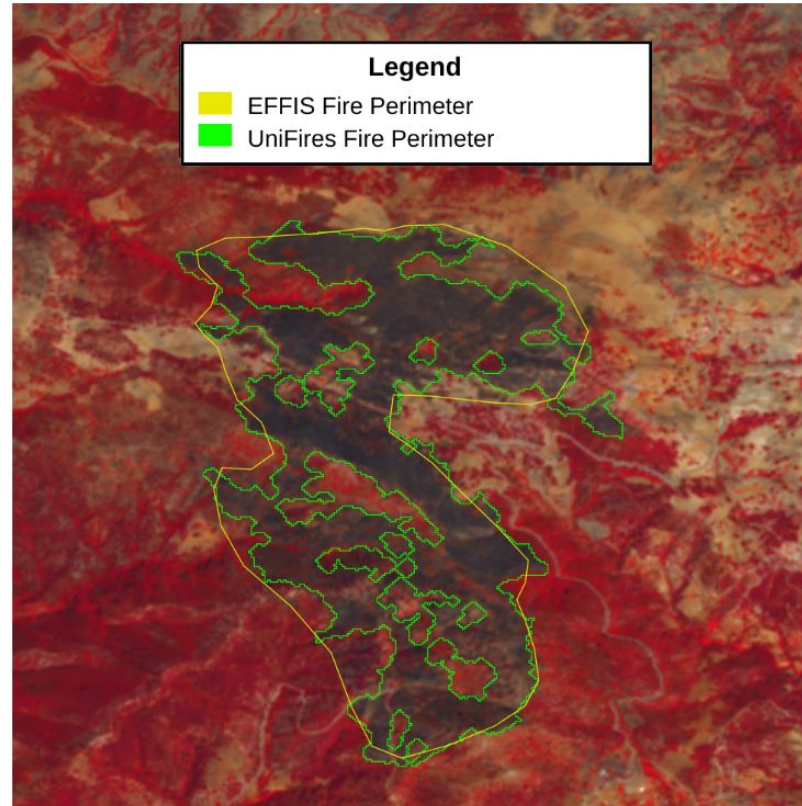
UniFireS dNBR Shp
(ID: 23749235)

Validation of UniFireS Dataset to EFFIS Dataset

- **Overall accuracy:** 95.61%
- **F1-Score:** 0.742
- **Precision:** 80.55%
- **Recall:** 68.85%
- **Reasons for differences:**
 - EFFIS utilizes MODIS imagery at 250m then manually reviews and updates perimeters based on Sentinel 2 imagery
 - 20m EFFIS resolution vs 10m UniFireS

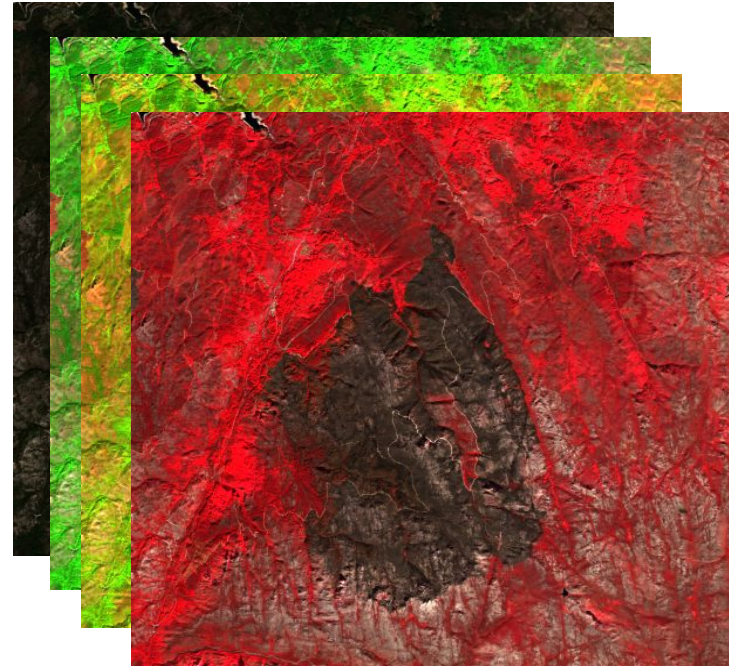
		EFFIS Results	
		Burned	Non-
UniFireS Results	Burned	11702498	200233
	Non-	375150	829319

UniFireS Dataset vs EFFIS Dataset



Overview of Finalized Dataset

- **Imagery Variables**
 - 6 Images - pre-fire, onfire, post-fire
 - 12 bands
 - Burn Mask - 10m resolution



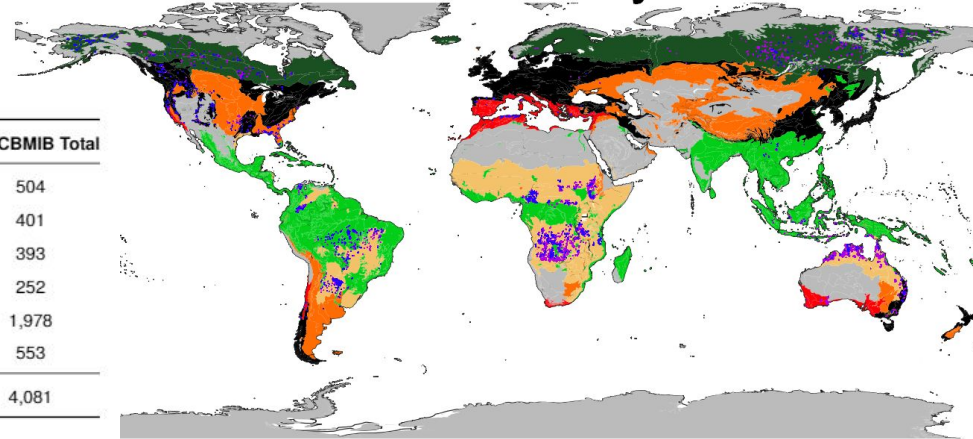
Post Fire False Imagery (Id: 23749235)

Distribution of Dataset - Biome

Biome Type	CA Total	CALC Total	Downloaded Total	CALCBMI Total	CALCBMIB Total
Boreal Forests	157,099	8,483	1,310	541	504
Mediterranean Forests	84,470	18,967	1,060	406	401
Temperate Forest	96,607	2,224	991	446	393
Temperate Grasslands & Savannas	90,543	1,650	772	300	252
Tropical & Subtropic Savanna	992,265	134,670	6,766	1,984	1,978
Tropical Forest	194,739	1,644	1,780	571	553
Grand Total	1,615,723	178,638	12,679	4,248	4,081

Table 9.2 Comparison of available fires per biome through the filtering process.

Burn Indexed Fires by Biome



Legend

- Country Borders
- Land Cover Groups
Tropical Forest
- Temperate Forest
- dNBR Fires
- Tropical & Subtropic Savanna
- Mediterranean Forests
- RdNBR Fires
- Temperate Grasslands & Savannas
- Boreal Forests
- RBR Fires
- Others

Distribution of Dataset - Land Cover

Map Code	Land Cover Class	CALCBMIB Fire Count	CALCBMIB Total Area (ha)	Average Fire Size (ha)
20	Schrubs	121	587,886.8	4,858.6
30	Herbaceous Vegetation	216	888,552.0	4,113.7
90	Herbaceous Wetland	20	32,090.3	1,604.5
111	Closed Forest, Evergreen Needle Leaf	427	1,760,509.7	4,123.0
112	Closed Forest, Evergreen, Broad Leaf	431	1,534,390.0	3,560.1
113	Closed Forest, Deciduous Needle Leaf	187	1,283,775.2	6,865.1
114	Closed Forest, Deciduous Broad Leaf	858	7,145,102.6	8,327.6
115	Closed Forest, Mixed	6	8,392.7	1,398.8
116	Closed Forest, Unknown	270	954,076.4	3,533.6
121	Open Forest, Evergreen Needle Leaf	12	37,513.7	3,126.1
122	Open Forest, Evergreen Broad Leaf	6	3,388.4	564.7
124	Open Forest, Deciduous Broad Leaf	551	9,461,606.8	17,171.7
126	Open Forest, Unknown	976	3,205,043.8	3,283.9
Total		4,081	26,902,328.4	6,592.1

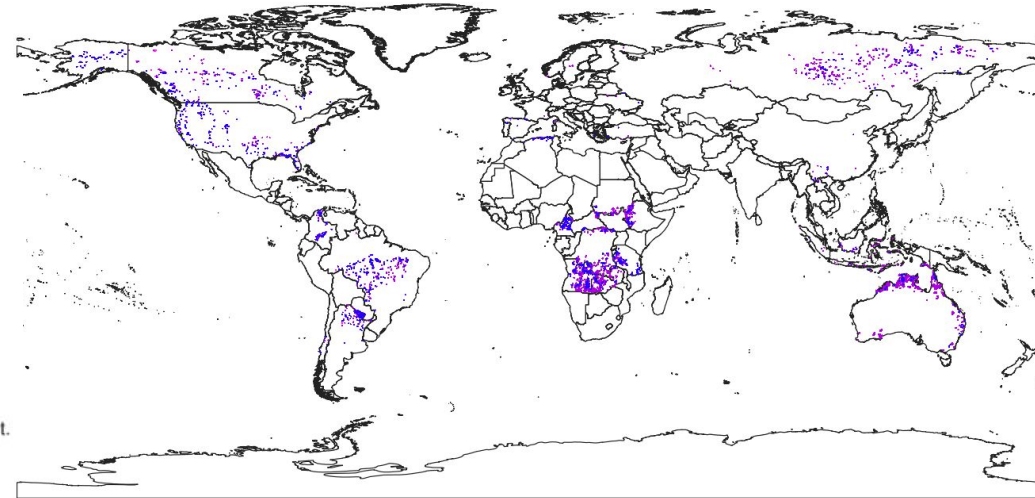
Table 9.7 Total fires per land cover that can be found within the complete CALCBMIB dataset.

Distribution of Dataset - Burn Index

Fires by Burn Index

Biome	dNBR Count	RBR Count	RdNBR Count	Total
Boreal Forests	188	10	290	488
Mediterranean Forests	43	0	29	72
Temperate Forest	185	7	67	259
Temperate Grasslands & Savannas	108	3	58	169
Tropical & Subtropic Savanna	589	51	1,820	2,460
Tropical Forest	261	19	353	633
Total	1,374	90	2,617	4,081

Table 9.6 Count of fires by burn mask that can be found within the complete CALCBMIB dataset.



Legend

- dNBR Fires
- RdNBR Fires
- RBR Fires
- Country Outlines

References

1. Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., Noss, R., Hansen, M., Locke, H., Ellis, E. C., Jones, B., Barber, C. V., Hayes, R., Kormos, C., Martin, V., Crist, E., ... Saleem, M. (2017). An ecoregion-based approach to protecting half the terrestrial realm. *BioScience*, 67(6), 534–545. <https://doi.org/10.1093/biosci/bix014>
2. Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. (2001). Terrestrial ecoregions of the world: A new map of life on Earth. *BioScience*, 51(11), 933. [https://doi.org/10.1641/0006-3568\(2001\)051\[0933:teotwa\]2.0.co;2](https://doi.org/10.1641/0006-3568(2001)051[0933:teotwa]2.0.co;2)
3. Padilla, M., Stehman, S. V., & Chuvieco, E. (2014). Validation of the 2008 MODIS-MCD45 global burned area product using stratified random sampling. *Remote Sensing of Environment*, 144, 187–196. <https://doi.org/10.1016/j.rse.2014.01.008>
4. Hantson, S., Padilla, M., Corti, D., & Chuvieco, E. (2013). Strengths and weaknesses of MODIS hotspots to characterize global fire occurrence. *Remote Sensing of Environment*, 131, 152–159. <https://doi.org/10.1016/j.rse.2012.12.004>
5. Stroppiana, D., Boschetti, L., Boschetti, M., Ranghetti, L., & Sali, M. (2021, March 24). ESA CCI ECV Fire Disturbance: D1.3 Product Validation Plan, version 2. ESA Climate Office. <https://climate.esa.int/en/projects/fire/key-documents/>
6. Buchhorn, M., Smets, B., Bertels, L., Roo, B. D., Lesiv, M., Tsendbazar, N.-E., Li, nlin L., & Tarko, A. (2020, September 8). Copernicus Global Land Service: Land Cover 100m: Version 3 Globe 2015-2019: Product User Manual. Zenodo. <https://zenodo.org/record/3938963>
7. European Forest Fire Information System (EFFIS). (2022). EFFIS European Fire Database. European Forest Fire Information System EFFIS. <https://effis.jrc.ec.europa.eu/apps/data.request.form/>