Fully automated burned area mapping using Sentinel-2 imagery and following the multiple spectral–spatial classification approach

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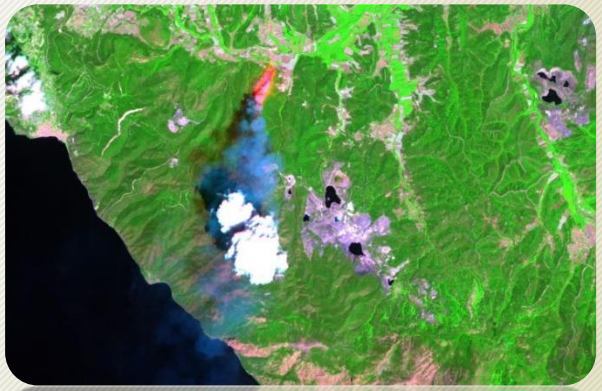
Mapping burned areas

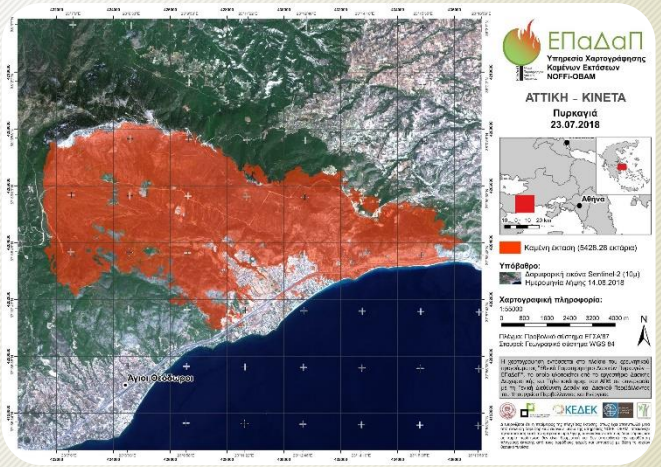
- **Sentinel-2** has been providing a wealth of high-resolution information with short revisit cycles
- Its spatial and temporal resolution makes it perfect for operational, near real-time burned area mapping
- High spatial resolution if images incommodes automated mapping, due to increased spatial and spectral variability



NOFFi-OBAM

- Proposed algorithm: improvement of **NOFFi-OBAM**, the object-based burned area mapping service developed within the Greek National Observatory of Forest Fires (NOFFi)

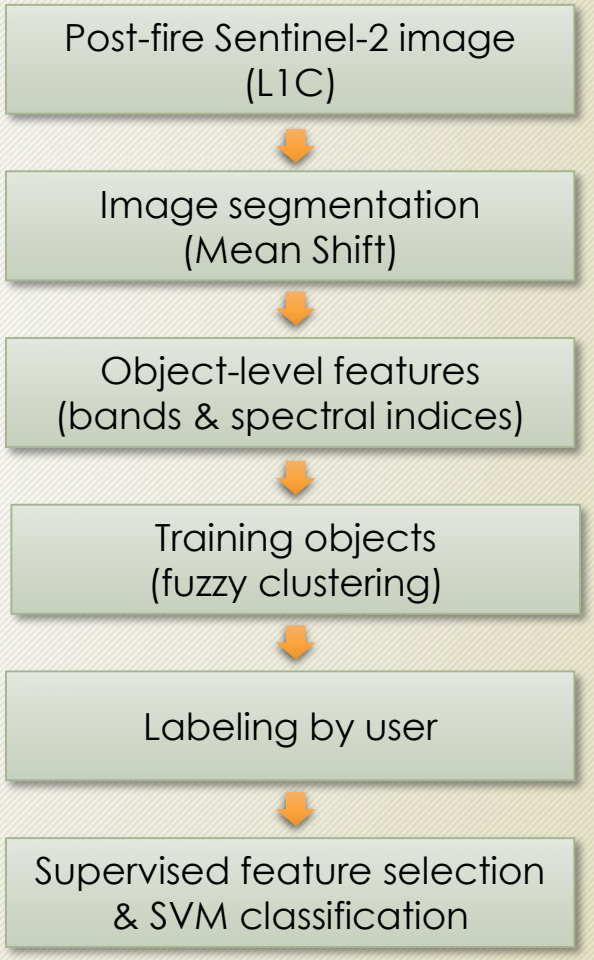
- NOFFi-OBAM has been employed operationally from 2016–2018 in Greece (and continues in 2019), mapping more than 150 wildfires with a total burned area of approximately 57,000 ha



Original NOFFi-OBAM algorithm

NOFFi-OBAM's workflow:

1) Post-fire Sentinel-2 image download (L1C – Top of Atmosphere reflectance)
2) Image segmentation → objects
3) Object-level features calculation (bands, spectral indices, textural features)
4) Automatic training object selection (Fuzzy C-Means clustering)
5) Labeling of training object by user through photointerpretation
6) Supervised feature selection → Support Vector Machine (SVM) classification → burned area perimeter



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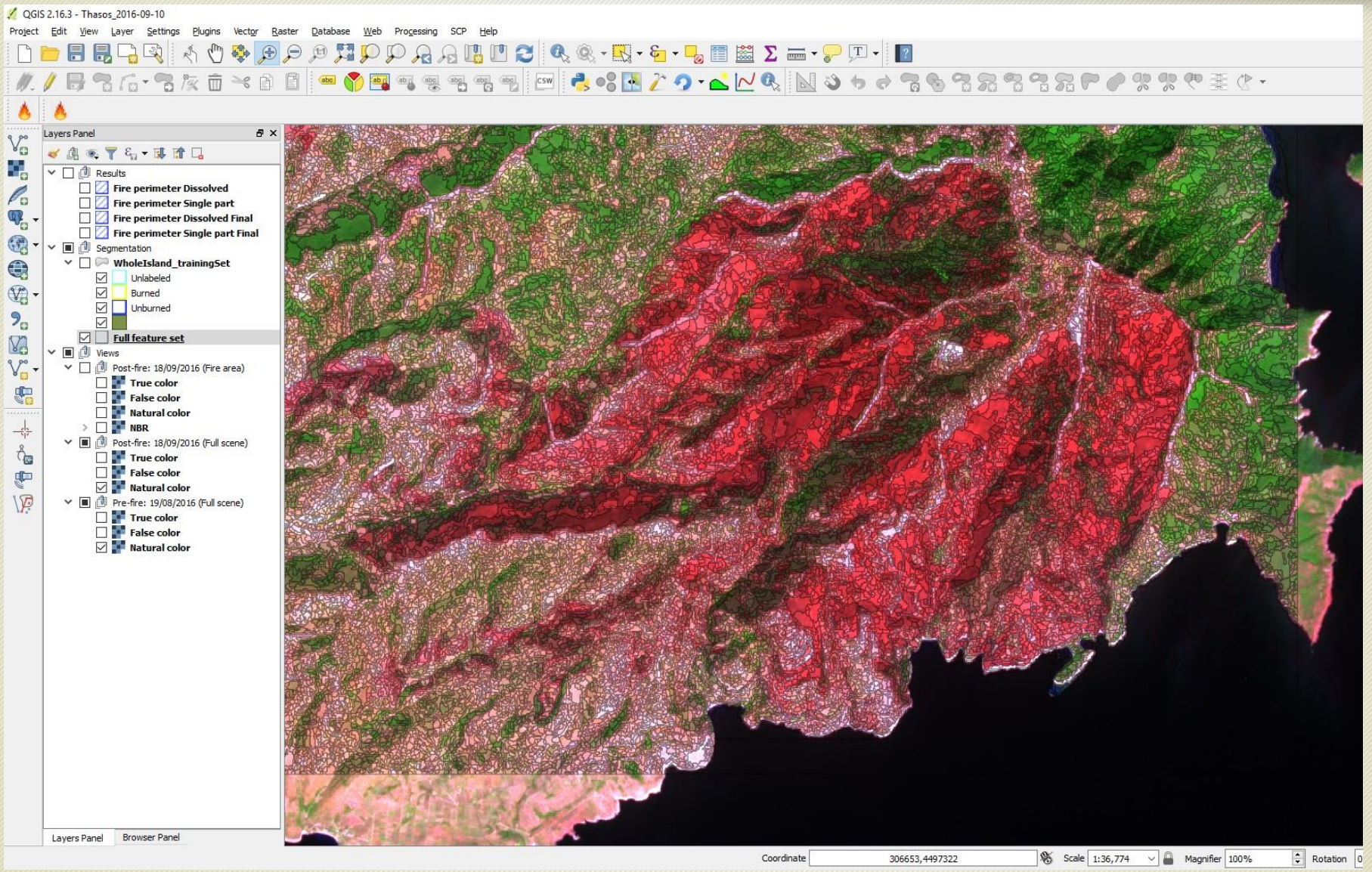

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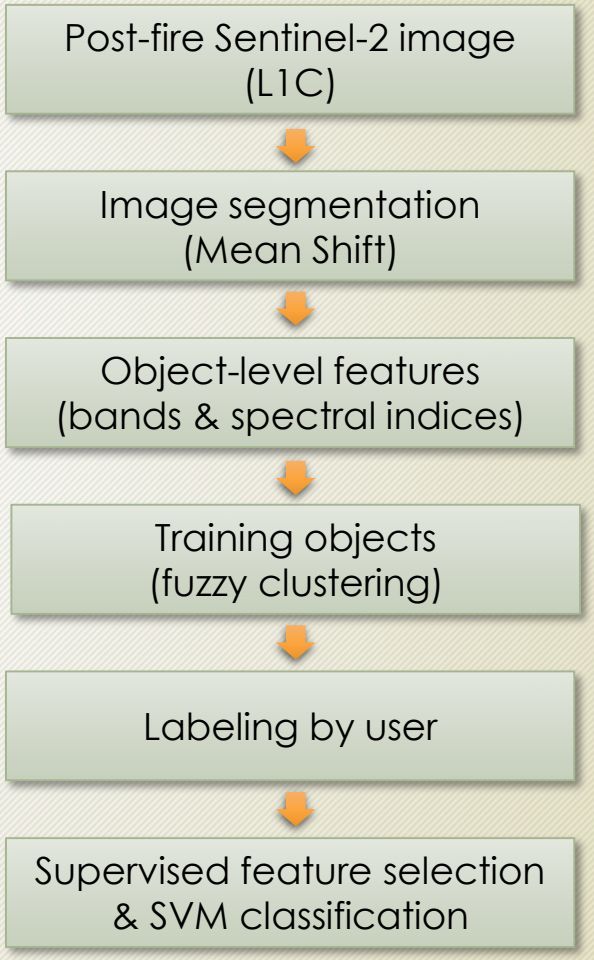

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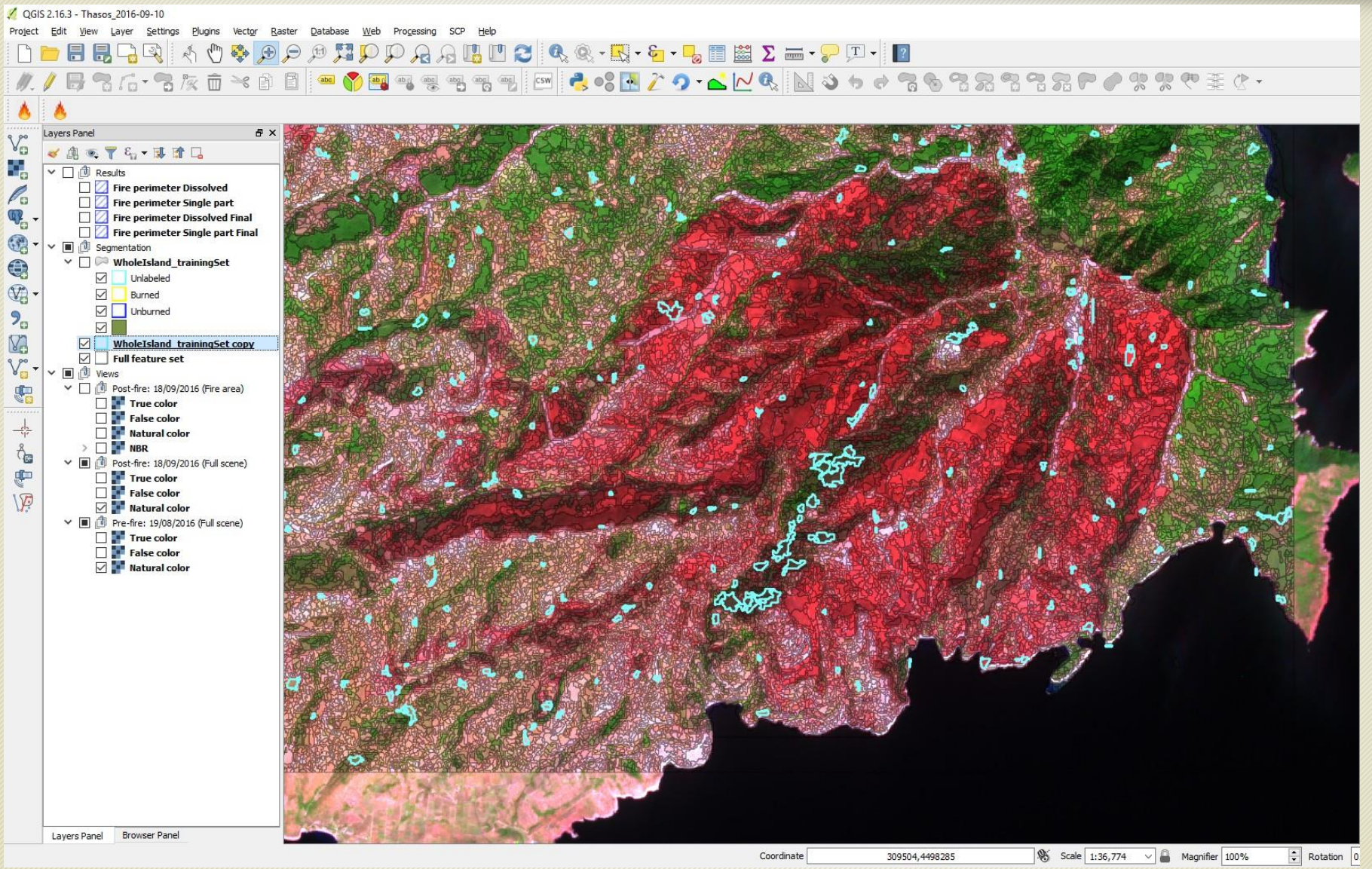

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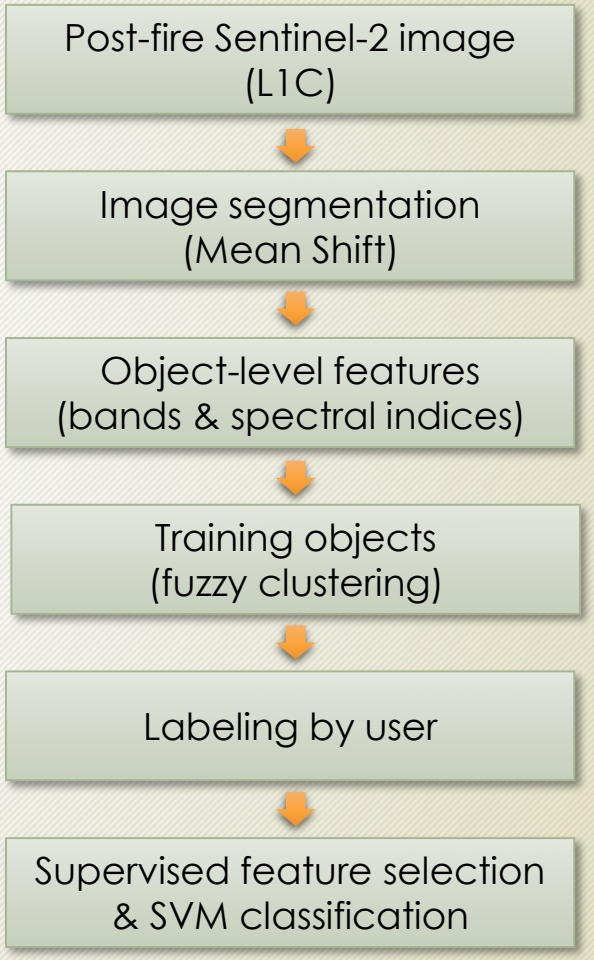

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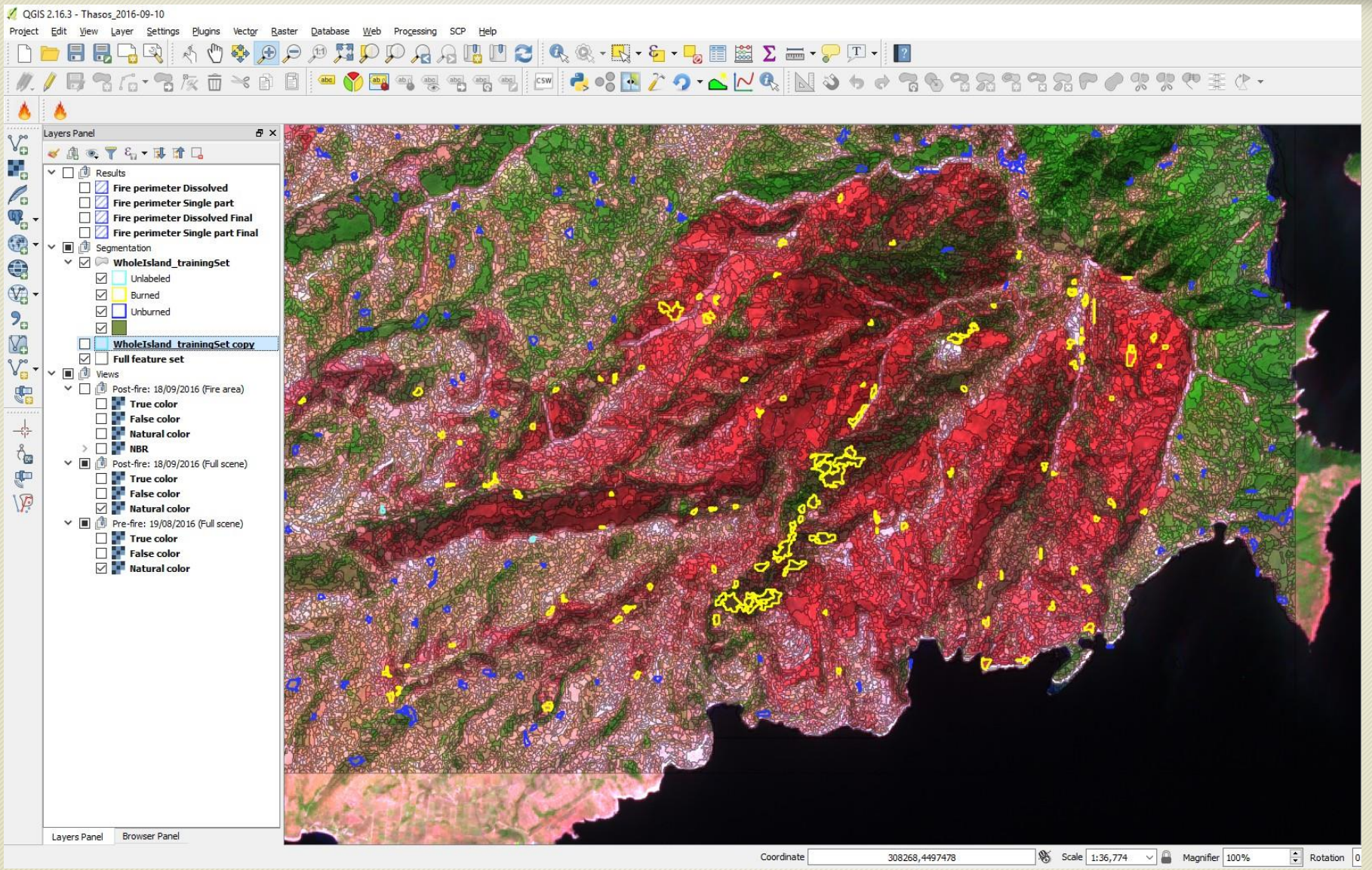

Original NOFFi-OBAM algorithm

NOFFi-OBAM's workflow:

1) **Post-fire Sentinel-2** image download (L1C – Top of Atmosphere reflectance)
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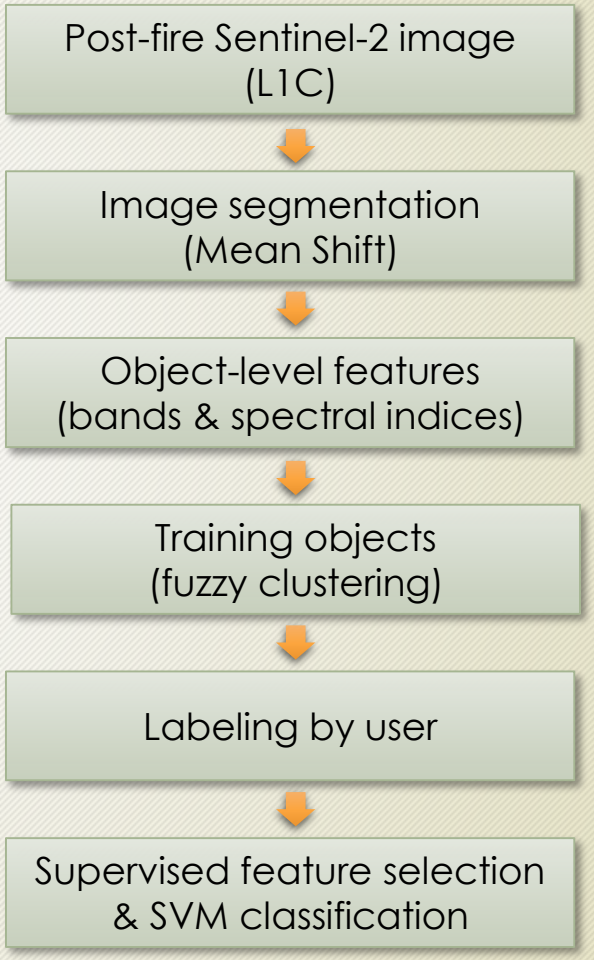
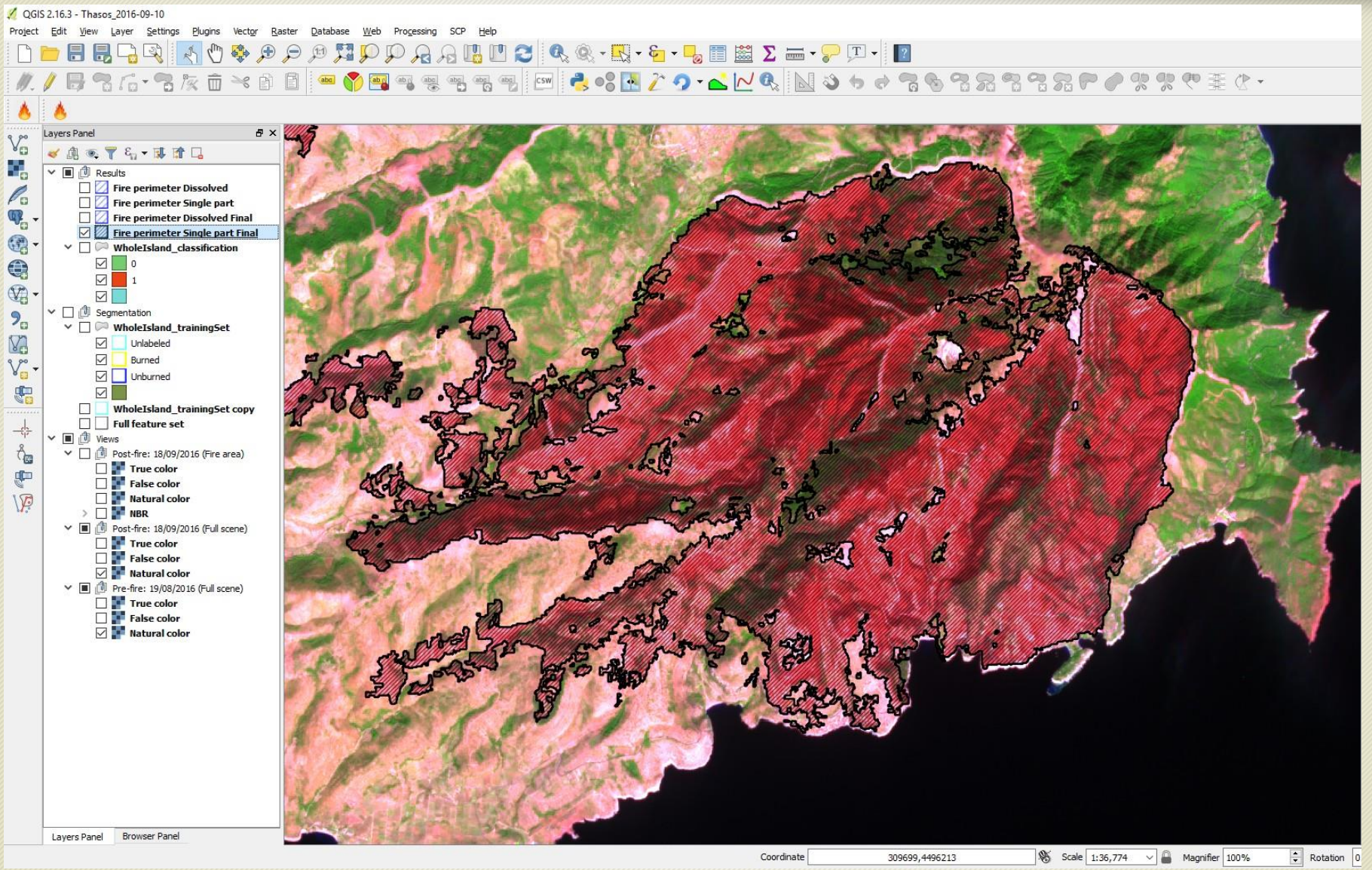
5) **Labeling** of training object **by user** through photointerpretation
6) Supervised feature selection → Support Vector Machine (SVM) classification → **burned area perimeter**



Original NOFFi-OBAM algorithm

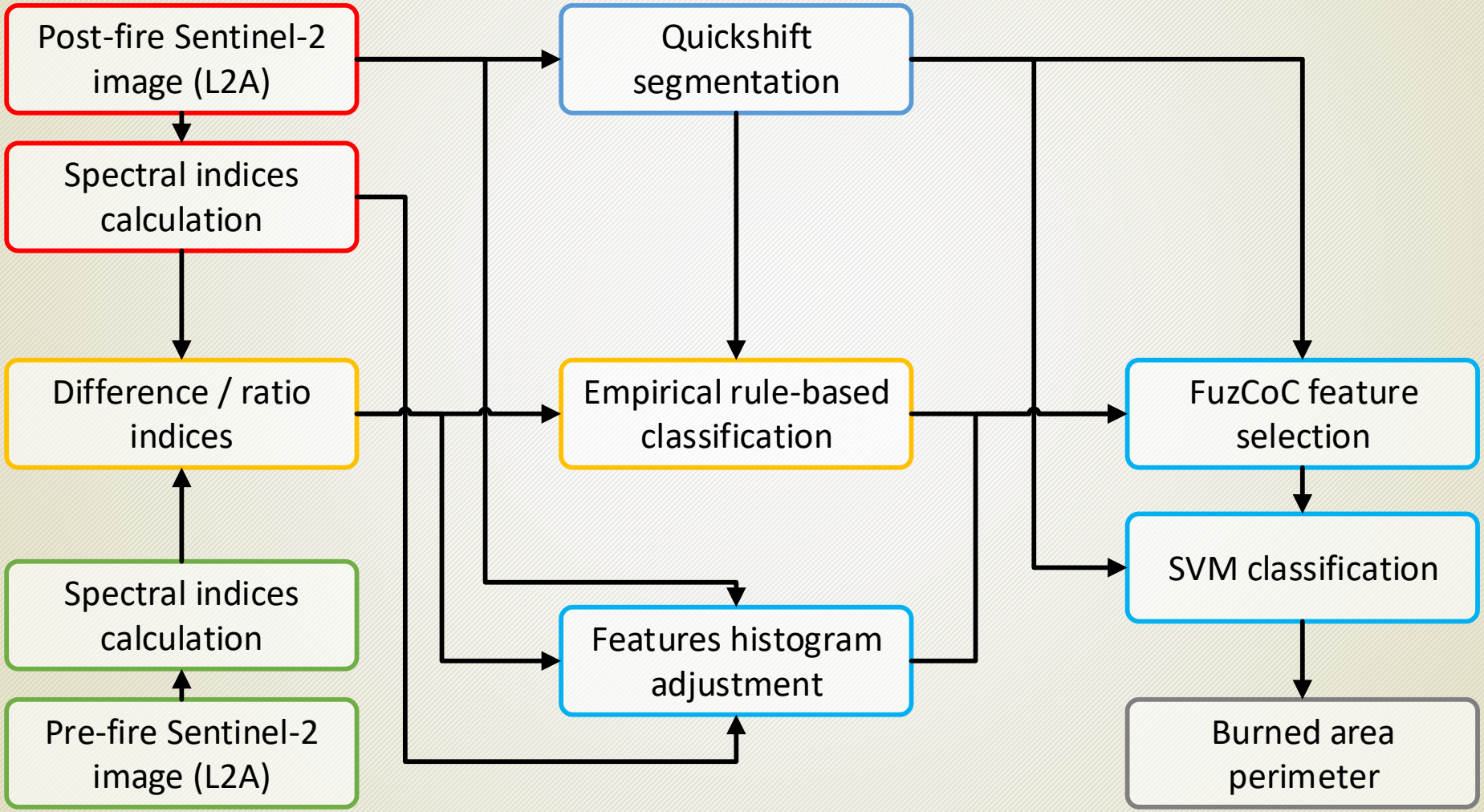


Original NOFFi-OBAM algorithm

- Pros:
  - Good mapping accuracy
  - Mostly automated workflow
  - Usually fast process (2–5 hours per wildfire; not including image downloading and manual part of preprocessing)

- Cons:
  - Pre-fire image was typically needed to assist photointerpretation
  - User had to manually label the training set (100–500 objects)
  - Time-consuming repeated process if user labeled some objects erroneously

New methodology: Workflow



New methodology: Stage 1

- Post-fire Sentinel-2 image:
  - Level 2A (Bottom of atmosphere reflectance)
  - Land mask from official NUTS 1 perimeter
  - Bands: Blue (2), Green (3), Red (4), Red-edge (6), NIR (8), NIRNarrow (8A), SWIRS (11), SWIRL (12)
  - Spectral indices (using Sentinel-2 band 8A as NIR):

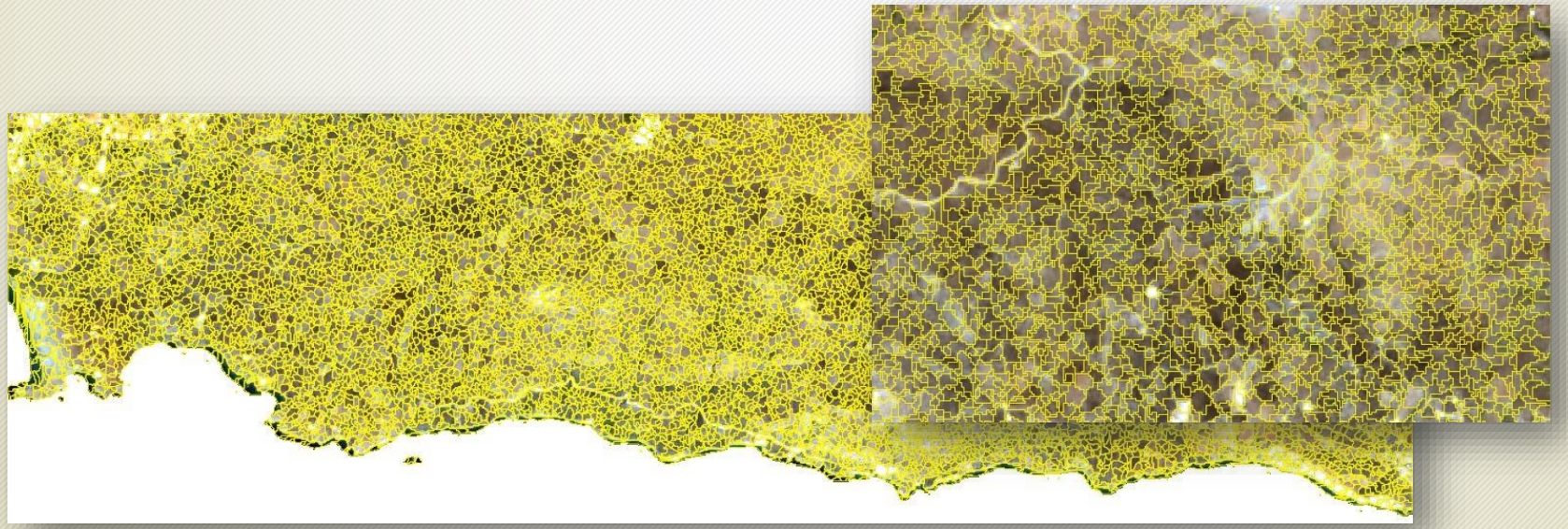
Acronym	Name	Equation
NDVI	Normalized difference vegetation index	(B8A – B04) / (B8A + B04)
MSAVI2	Modified soil-adjusted vegetation index 2	$0.5 \cdot \left\{ 2 \cdot B8A + 1 - \sqrt{(2 \cdot B8A + 1)^2 - 8 \cdot (B8A - B04)} \right\}$
CSI	Char soil index	B8A / B12
MIRBI	Mid-infrared burn index	10·B12 – 9.8·B11 + 2
NBR	Normalized burn ratio	(B8A – B12) / (B8A + B12)
NBR2	Normalized burn ratio 2	(B11 – B12) / (B11 + B12)
NDII	Normalized difference infrared index	(B8A – B11) / (B8A + B11)
MNDWI	Modified normalized difference water index	(B03 – B11) / (B03 + B11)

New methodology: Stage 1

- Pre-fire Sentinel-2 image:
  - Level 2A (Bottom of atmosphere reflectance)
  - Land mask from official NUTS 1 perimeter
  - Spectral indices (using Sentinel-2 band 8A as NIR):
    - MIRBI (Mid-Infrared Burn Index)
    - NBR (Normalized Burn Ratio)
    - NBR2 (Normalized Burn Ratio 2)
    - NDII (Normalized Difference Infrared Index)
    - MDWI (Modified Normalized Difference Water Index)
- Difference / ratio indices (for classification feature set):
  - $NIR8A_{Ratio}$ [$Band8A_{prefire}$ / $Band8A_{postfire}$ − 1]
  - ΔMIRBI, ΔNBR, ΔNBR2, ΔNDII [$<Index>_{pre\text{-}fire}$ − $<Index>_{post\text{-}fire}$]

New methodology: Stage 2

- Post-fire image is segmented using:
  - 10 m Sentinel-2 bands only (2, 3, 4, and 8)
  - Quickshift[1] superpixel segmentation (oversegmentation) algorithm (approximation of kernelized mean-shift; local mode-seeking algorithm)



[1] Vedaldi, A.; Soatto, S. Quick Shift and Kernel Methods for Mode Seeking. In Proceedings of the Computer Vision – ECCV 2008; Forsyth, D., Torr, P., Zisserman, A., Eds.; Springer Berlin Heidelberg, 2008; pp. 705–718.

New methodology: Stage 3

- Empirical rules on difference / ratio features → automated classification of unambiguous burned or unburned objects
  - Burned:

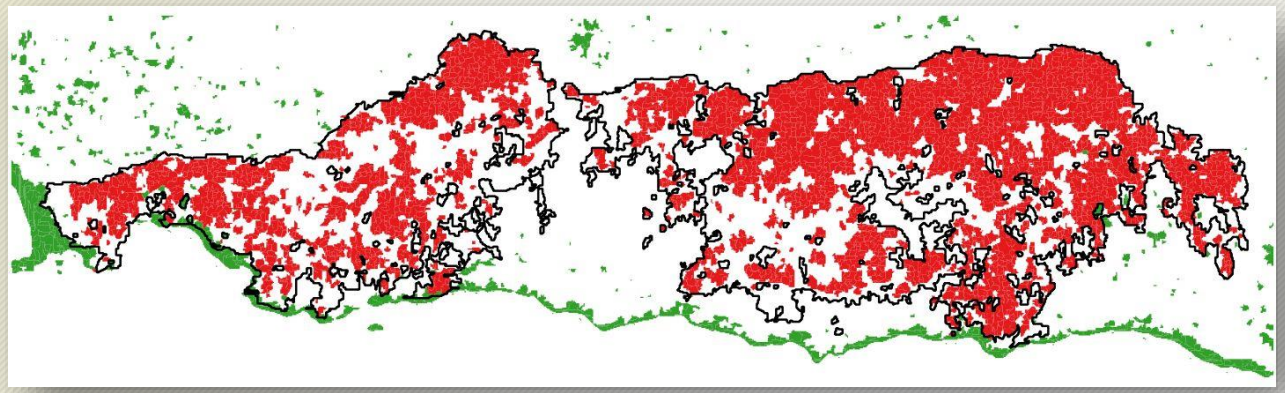
$$\mathrm{MNDWI}_{\mathrm{prefire}} < -0.3 \;\; AND$$
$$[(\mathrm{NIR8A}_{\mathrm{Ratio}} > 0.3 \;\; OR \;\; \Delta\mathrm{MIRBI} < -1.5) \;\; AND \; \Delta\mathrm{NDII} > 0.02]$$

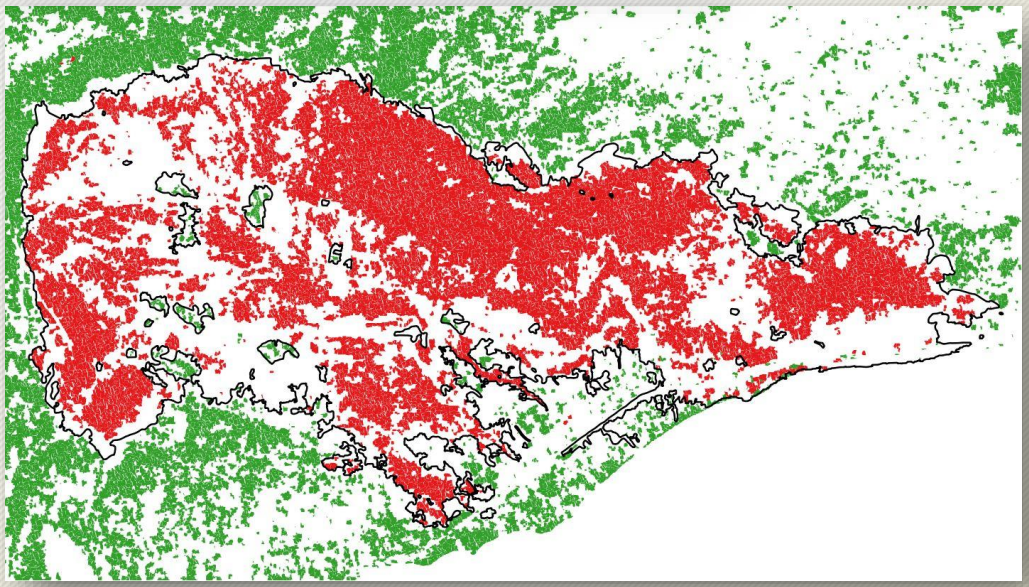
  - Unburned:

$$\mathrm{MNDWI}_{\mathrm{prefire}} > -0.25 \;\; OR \;\; [\Delta\mathrm{NBR2} < -0.015 \;\; OR \;\; \Delta\mathrm{NBR} < -0.015]$$

- We try to classify unambiguous unburned / burned objects only → training set fro supervised classification

New methodology: Stage 3





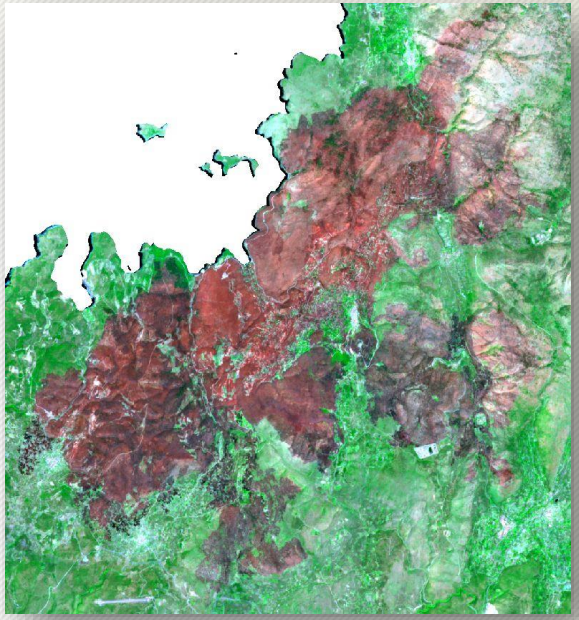
New methodology: Stage 4

- Features for classification:
  - ✓ Post-fire bands & spectral indices, difference / ratio indices
  - ✓ Each feature is normalized in [0,1] after removing the bottom 1% and top 1% of the image histogram
  - ✓ Mean values of each feature within the object
- Supervised feature selection using the FuzCoC (fuzzy complementary criterion) algorithm[1]
- Train an SVM classifier using the training set (from empirical rules) and employ it to obtain the burned area perimeter

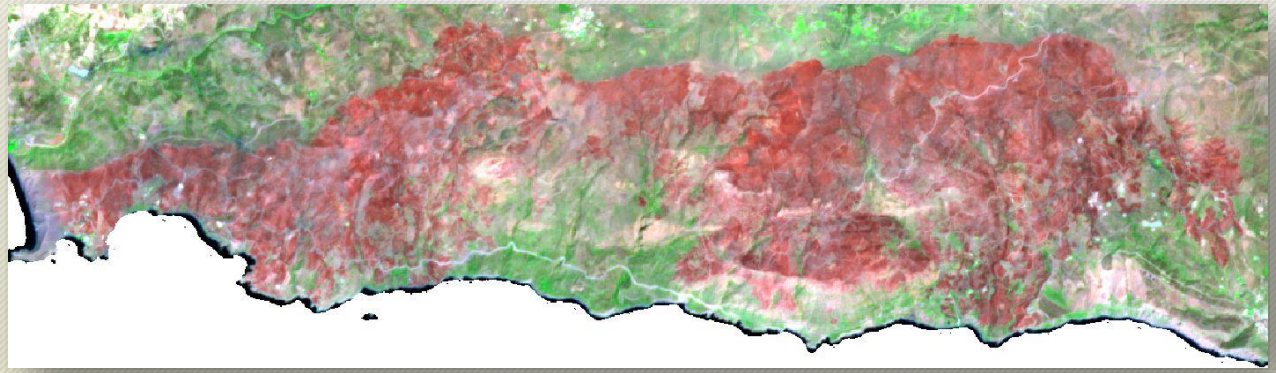
[1] Moustakidis, S.P.; Theocharis, J.B.; Giakas, G. Feature selection based on a fuzzy complementary criterion: application to gait recognition using ground reaction forces. *Computer Methods in Biomechanics and Biomedical Engineering* **2011**, *15*, 627–644.

New methodology: Test cases

Farakla, Euboea, 2016

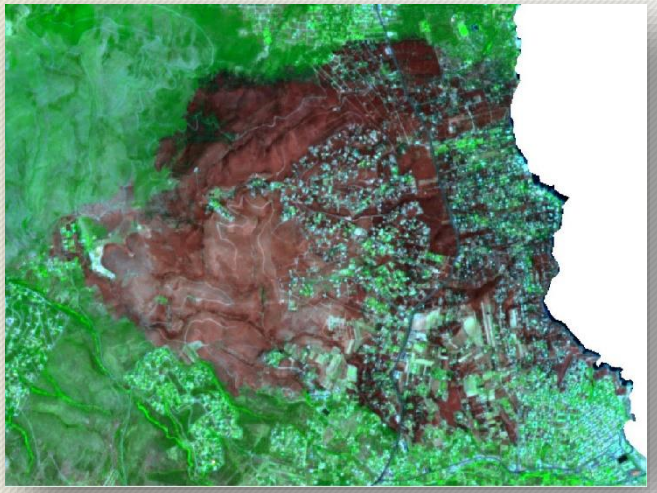


Elata, Chios, 2016



Saktouria, Crete, 2016

New methodology: Test cases



Kallitechnoupoli (Mati), Attica, 2018

Zemeno,
Corinthia, 2018

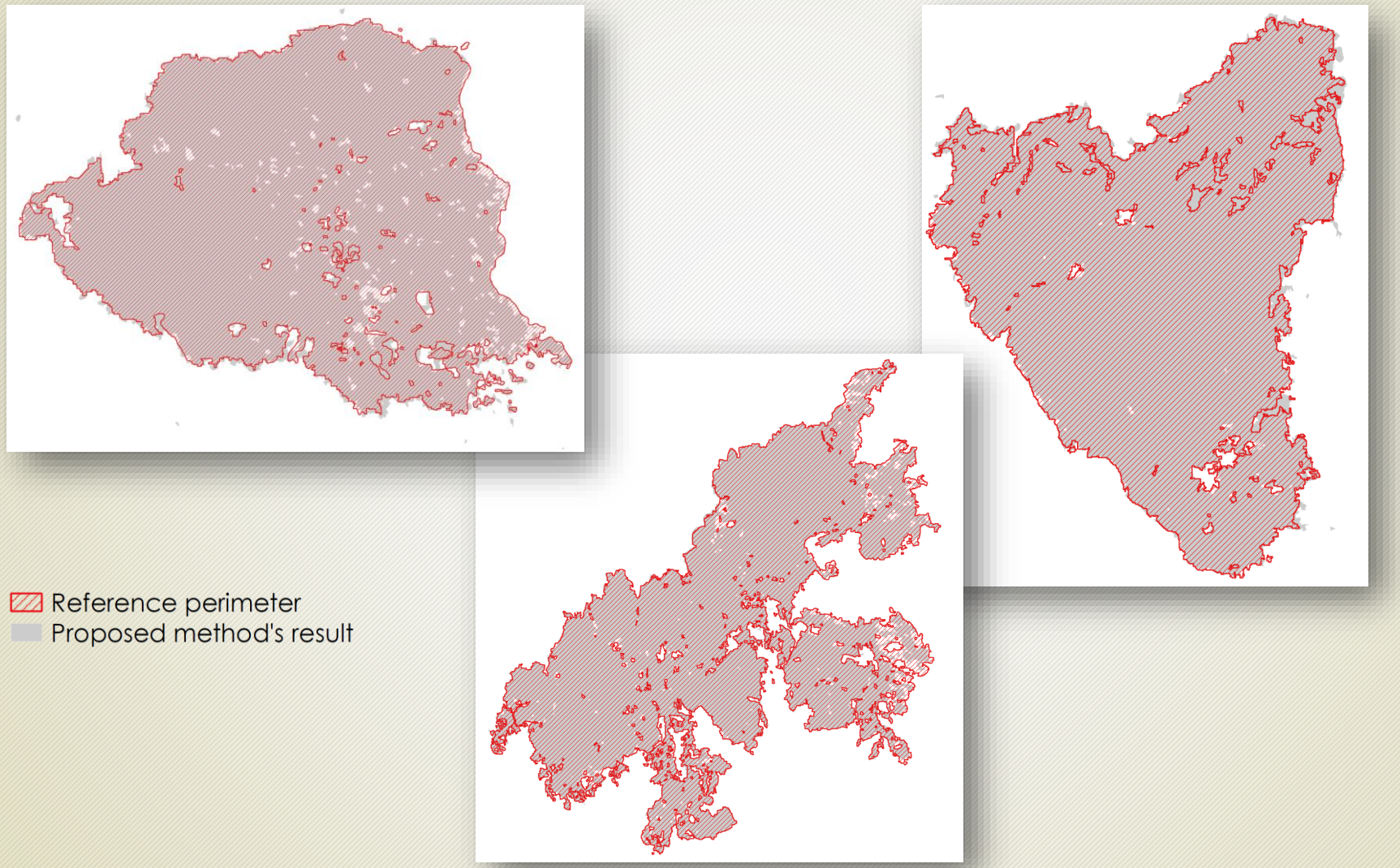
Kineta,
Attica, 2018

New methodology: Results

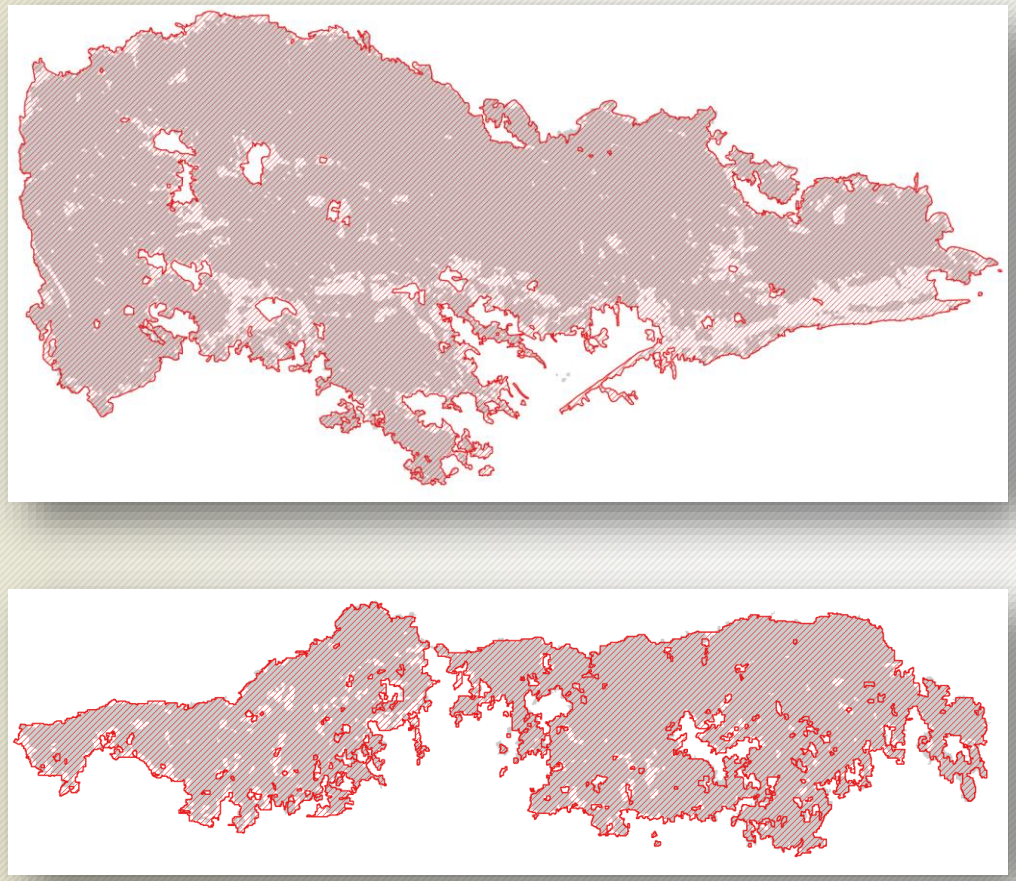
- Confusion matrix metrics:

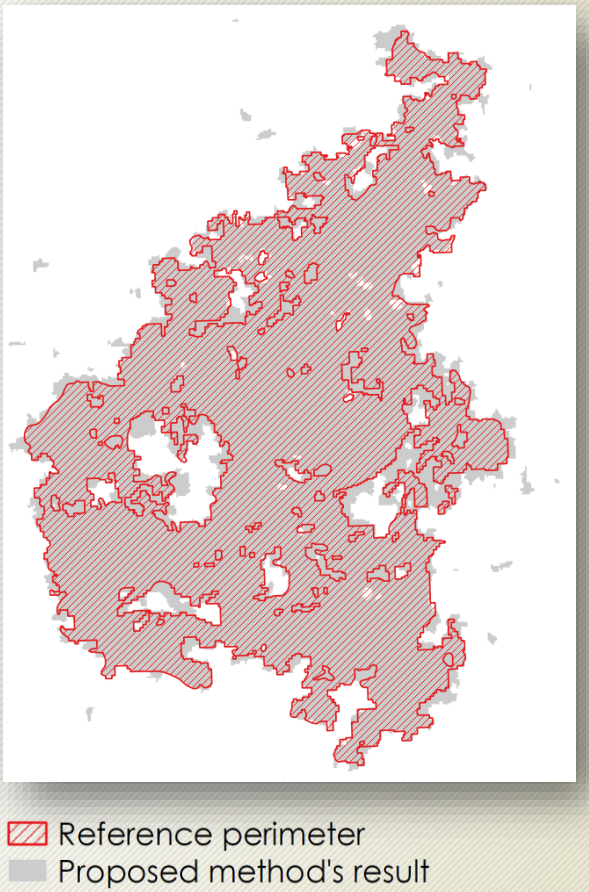
Area	Sensitivity	Specificity	Precision	Accuracy	F-measure
Elata	0.94	0.97	0.96	0.96	0.95
Farakla	0.99	0.94	0.94	0.96	0.97
Saktouria	0.89	0.97	0.96	0.93	0.92
Zemeno	0.98	0.90	0.83	0.93	0.90
Kallitechnoupoli	0.95	0.95	0.96	0.95	0.95
Kineta	0.84	0.99	0.99	0.92	0.91

New methodology: Results



New methodology: Results





Thank you for your attention!

NOFFi National Observatory of Forest Fires

Acknowledgements

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