Deep Learning Methods for Daily Wildfire Danger Forecasting

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Problem and Challenges

Wildfire danger forecasting as Machine Learning (ML) task.

Wildfire forecasting is not a typical ML problem and poses some major challenges [1].

- Wildfires caused by the **complex interactions of the fire drivers** (climate, vegetation, human activity), operating at different spatial and temporal scales.
- Wildfire **occurrence is inherently stochastic**. The lack of a fire event does not mean lack of fire danger.
- Wildfires affect humans and the environment in a multitude of ways. Crucial to go **beyond mere forecasting into understanding** with eXplainable AI (XAI).

Datacube

Open-access daily 1km x 1km datacube [2].

1253 km x 983 km, Eastern Mediterranean surrounding Greece, years 2009-2021.

Climate, **Vegetation**, **Human drivers**: Weather (ERA5), Satellite (MODIS), Soil Moisture (EDO), Topography (EU-DEM), Land Cover (Corine), Socioeconomic (Worldpop).

Output: Post-processed historical burned areas (JRC EFFIS).

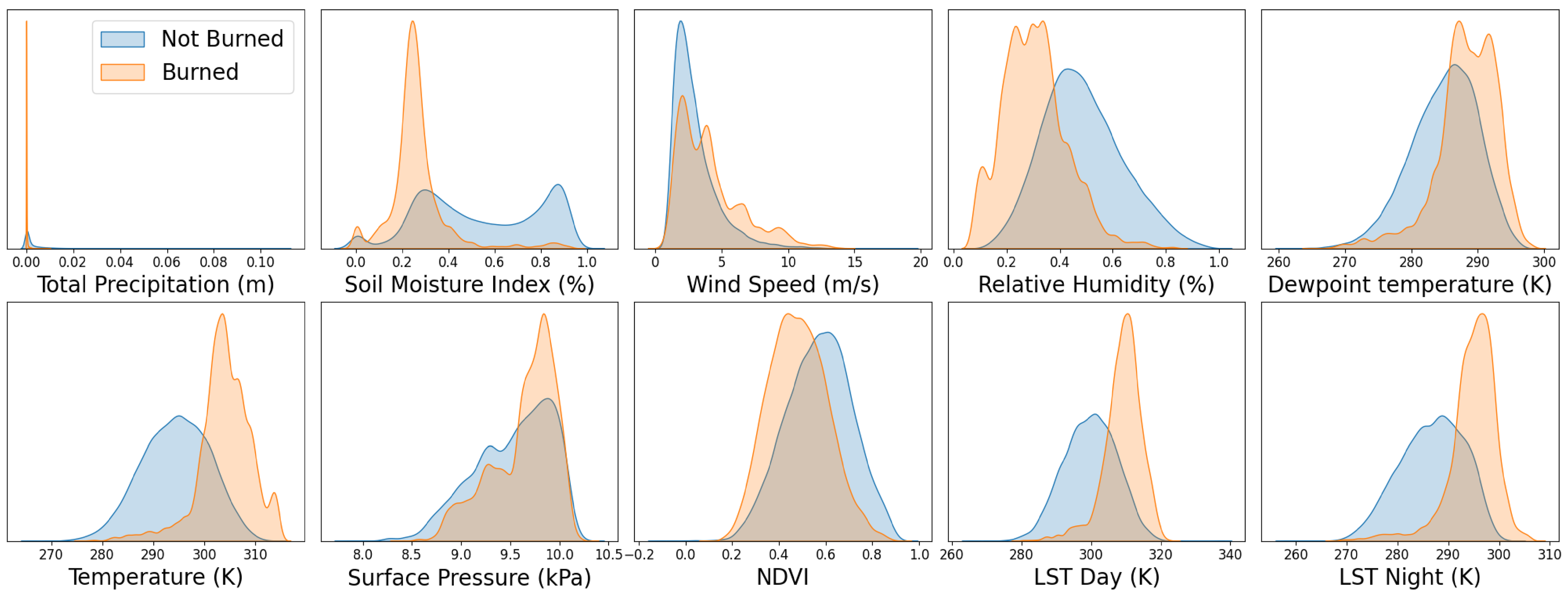

Figure 1: Distribution of input variables depending on the target.

Setup

- Three different types of datasets (pixel, temporal, spatio-temporal), each one for a different model i.e Random Forest (RF), LSTM and ConvLSTM (Fig. 2).
- Target is for all datasets the same; next-day's burned value.
- Positive/Negative Sampling: Positives are all included. Two times more negatives than positives on no fire days.
- Time split: Training in 2009-2019. Testing in 2020, a normal fire season, and 2021 an extreme fire season (Fig. 3).

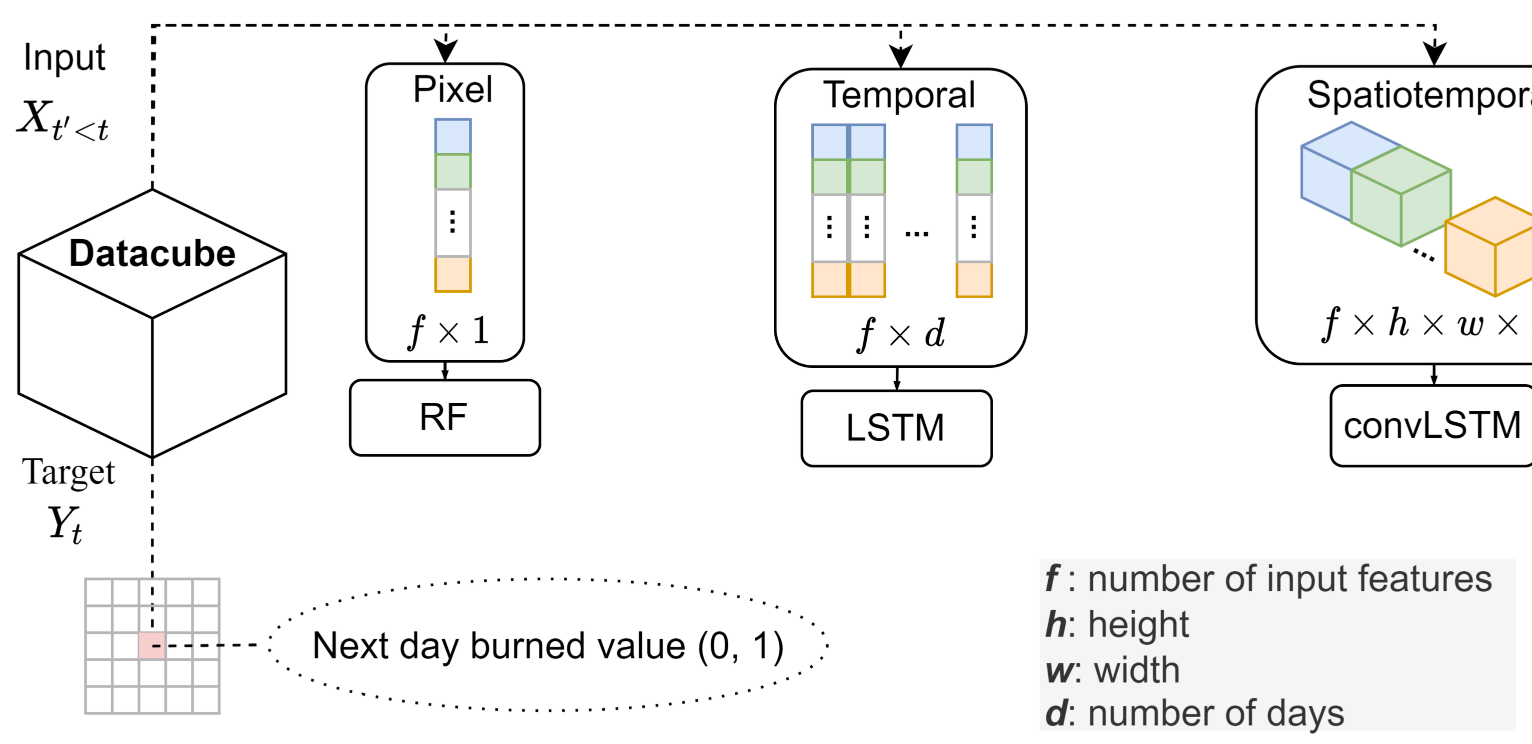

Figure 2: Dataset extraction and experimental setup.

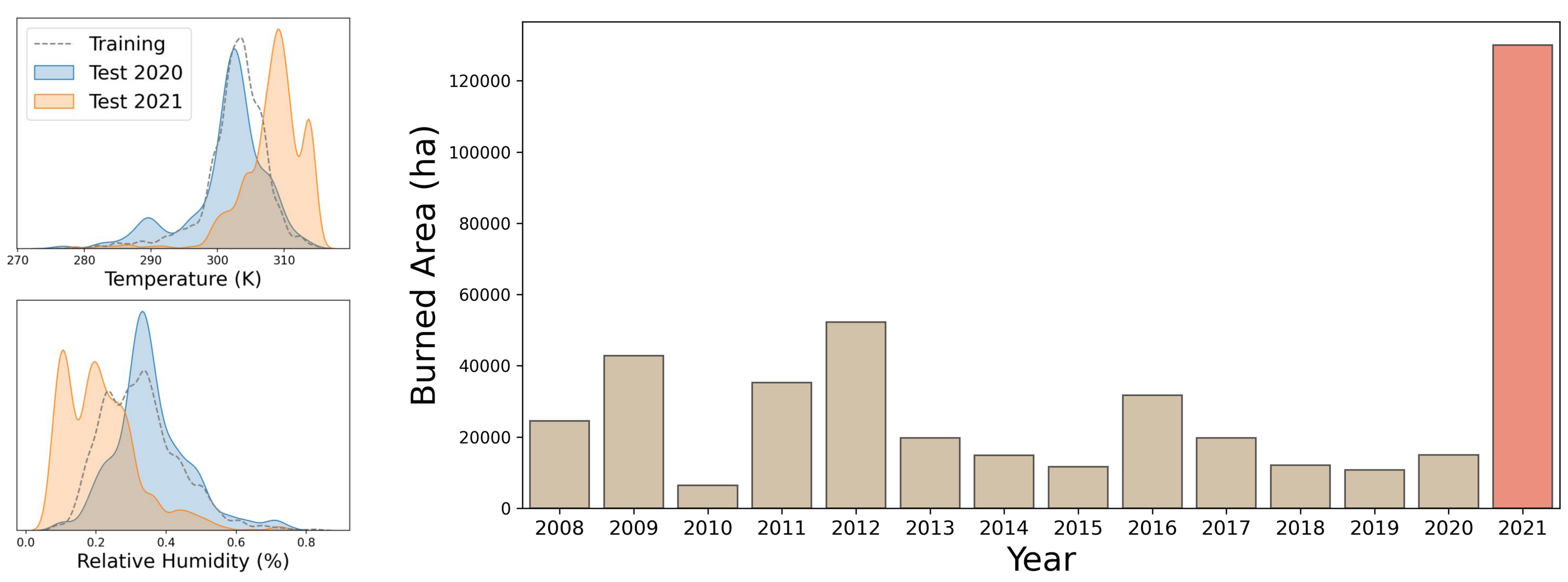

Figure 3: Difference in input variables (a) and (b) burned area for train and the test sets.

Results

- Deep Learning (DL) models better than RF (Table 1) and all models better than FWI (Fig. 4)
- **Temporal context** (LSTM) **sufficient** at a high degree.
- Produced dangers maps **demonstrate spatiotemporal variability** (Fig. 4).
- Models **generalize well for 2021, an extreme year** (Table 1, Fig. 5).

	(a) Results 2020			(b) Results 2021		
Model	Precision	Recall	F_1	Precision	Recall	F_1
RF	0.838	0.603	0.701	0.876	0.697	0.777
LSTM	0.865	**0.755**	0.806	0.901	**0.855**	**0.878**
ConvLSTM	**0.921**	0.716	**0.809**	**0.947**	0.804	0.867

Table 1: Performance of the models on the test sets (years 2020, 2021).

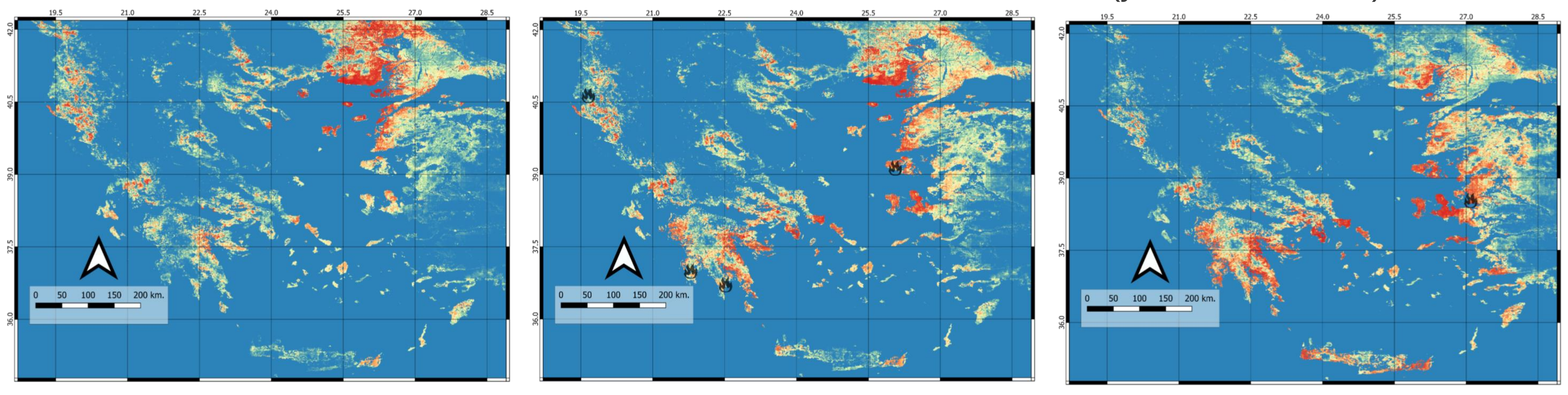

Figure 4: Fire Danger by LSTM for 3 consecutive days.

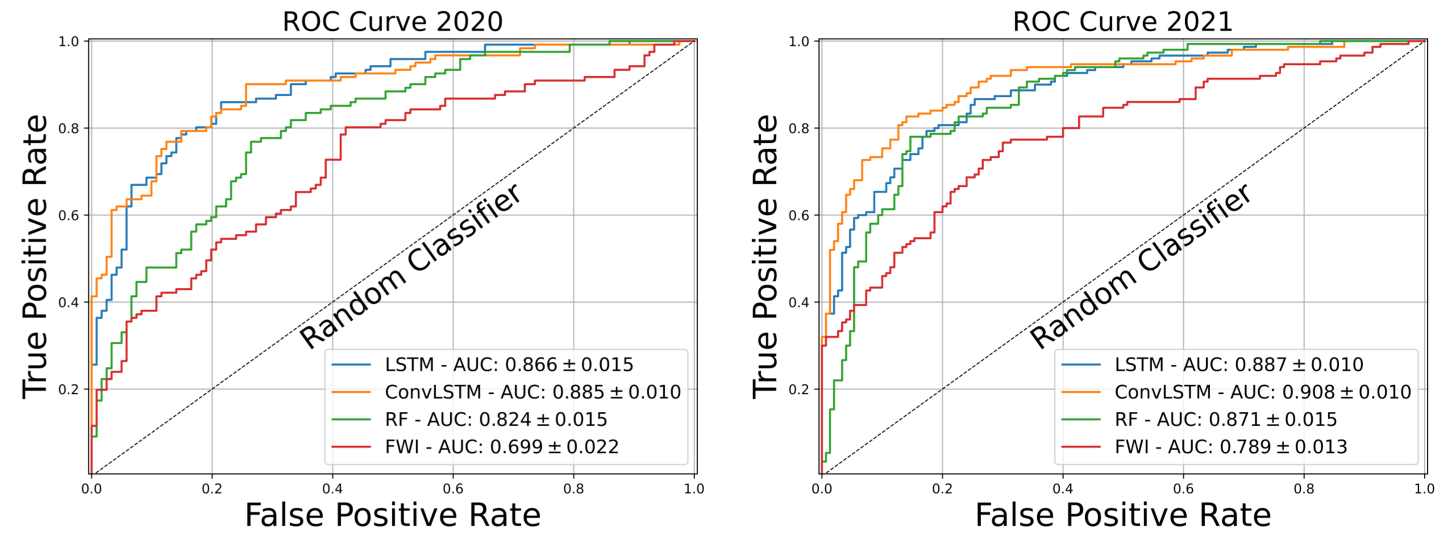

Figure 5: ROC curves and AUC values for LSTM, ConvLSTM, RF and FWI.

Explainability

- **Soil moisture, NDVI and weather** are the most important predictors (Fig. 6).
- Changes in their importance across events reveal **diverse wildfire types** (Fig. 7).
- *XAI* uncovers **physically consistent associations and temporal dynamics** (Fig. 8)

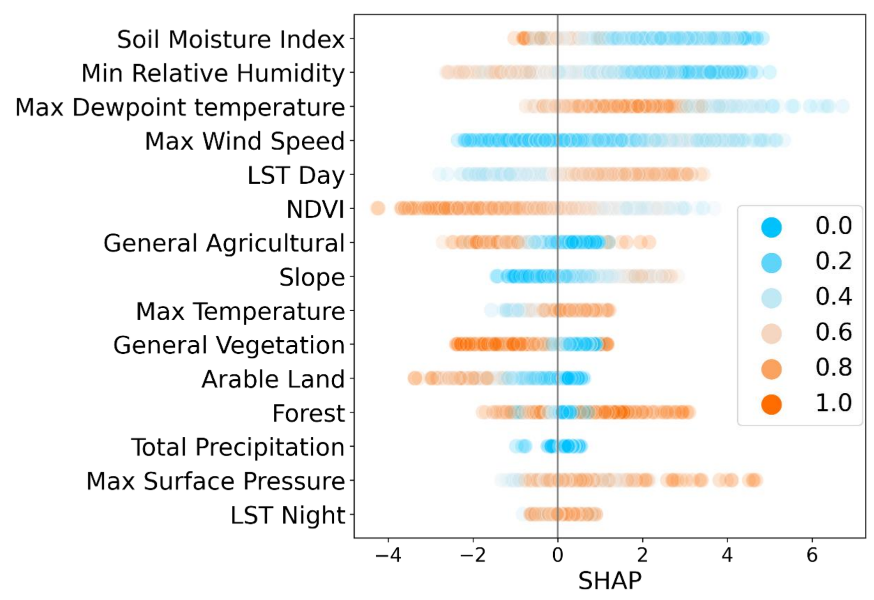

Figure 6: SHAP values for burned cells.

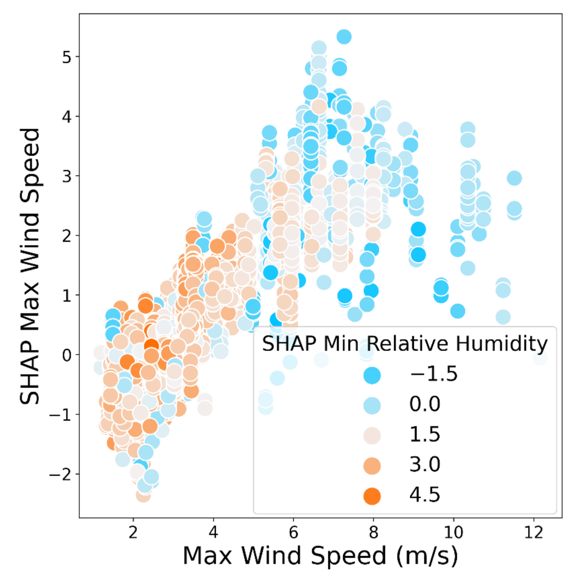

Figure 7: **Wind-driven** Vs **Drought-driven** wildfires.

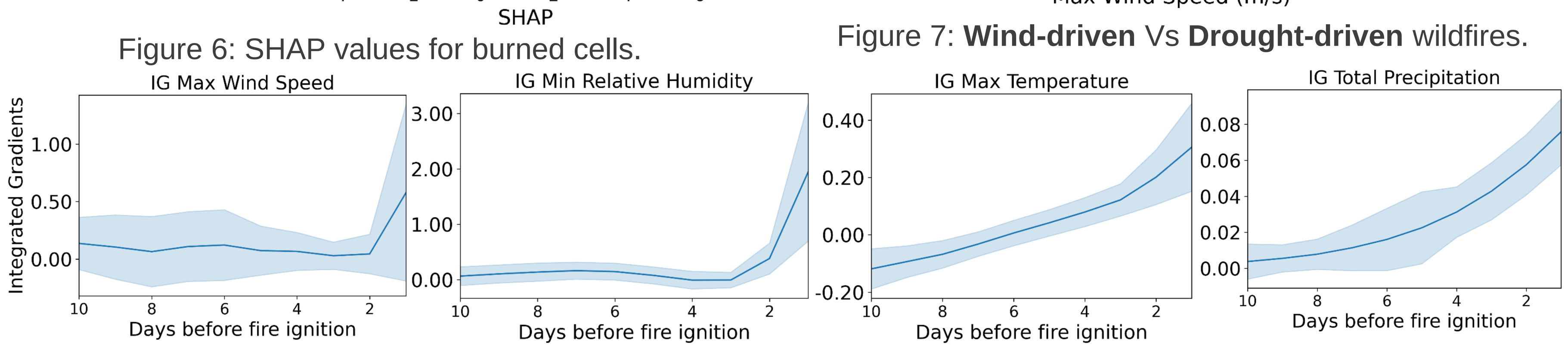

Figure 8: Learned **temporal dynamics** of the fire drivers.

Conclusion

- DL models predicting daily wildfire danger, **outperform the FWI**, improve wildfire forecasting and generalize *well even in the extreme year 2021.*
- Explainability reveals that **DL models learn meaningful interactions**.
- The presented methodology paves the way to more **robust, accurate and trustworthy data-driven anticipation** of wildfires.

References

[1] Prapas, Ioannis, et al. "Deep Learning Methods for Daily Wildfire Danger Forecasting." arXiv preprint arXiv:2111.02736 (2021).

[2] Prapas, Ioannis, et al. Firecube: A Daily Datacube for the Modeling and Analysis of Wildfires in Greece. 1.0, Zenodo, 1 May 2022, p., doi:10.5281/zenodo.6475592.

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