AOMSUC-15 FYSUC-2025
FIFTEENTH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE
THE JOINT 2025 FENGYUN SATELLITE USER CONFERENCE

Towards Real-Time Prediction of Indonesian Peatland Fires Propagation: A Combined WRF-Fire Model and Fengyun-3D Satellite Approach

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INTRODUCTION

Peatland covers **13.43 million hectare** and store **57 GtC carbon** storage. (Anda *et al.* 2021)

Peatland fires become the major destabilization and losses carbon storage. (Harenda *et al.* 2018; Nelson *et al.* 2021)

Model *Weather Research and Forecasting - Fire* (**WRF-Fire**) can be used as peatland **fire mitigation** tool

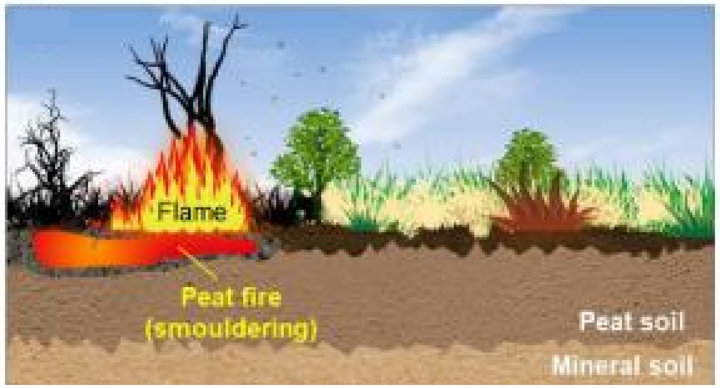


Fig. 1 Smouldering combustion
(Lin *et al.* 2021)

INTRODUCTION

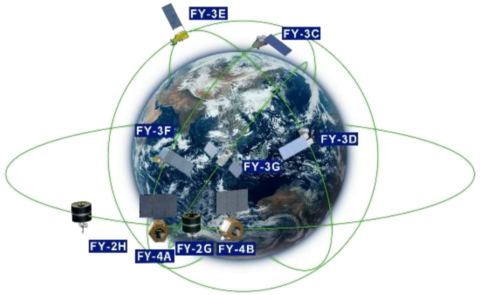
TOOLS

Ubuntu 20.04.4 *version*
PC operating system

Python 3.10.18

QGIS

DATAS



Fengyun-3D GFR

NCEP GFS 0.25°

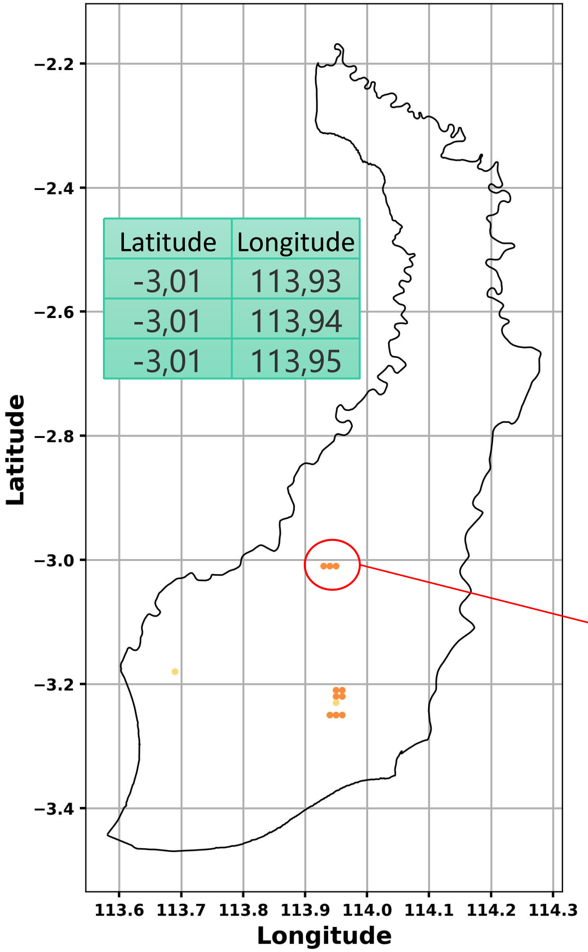
Sentinel-2

MODEL

WRF-Fire 4.2

METHOD

Fengyun-3D GFR



Latitude	Longitude
-3,01	113,93
-3,01	113,94
-3,01	113,95

Case Study 2nd October 2023, at 09:30 WIB (02:30 UTC)

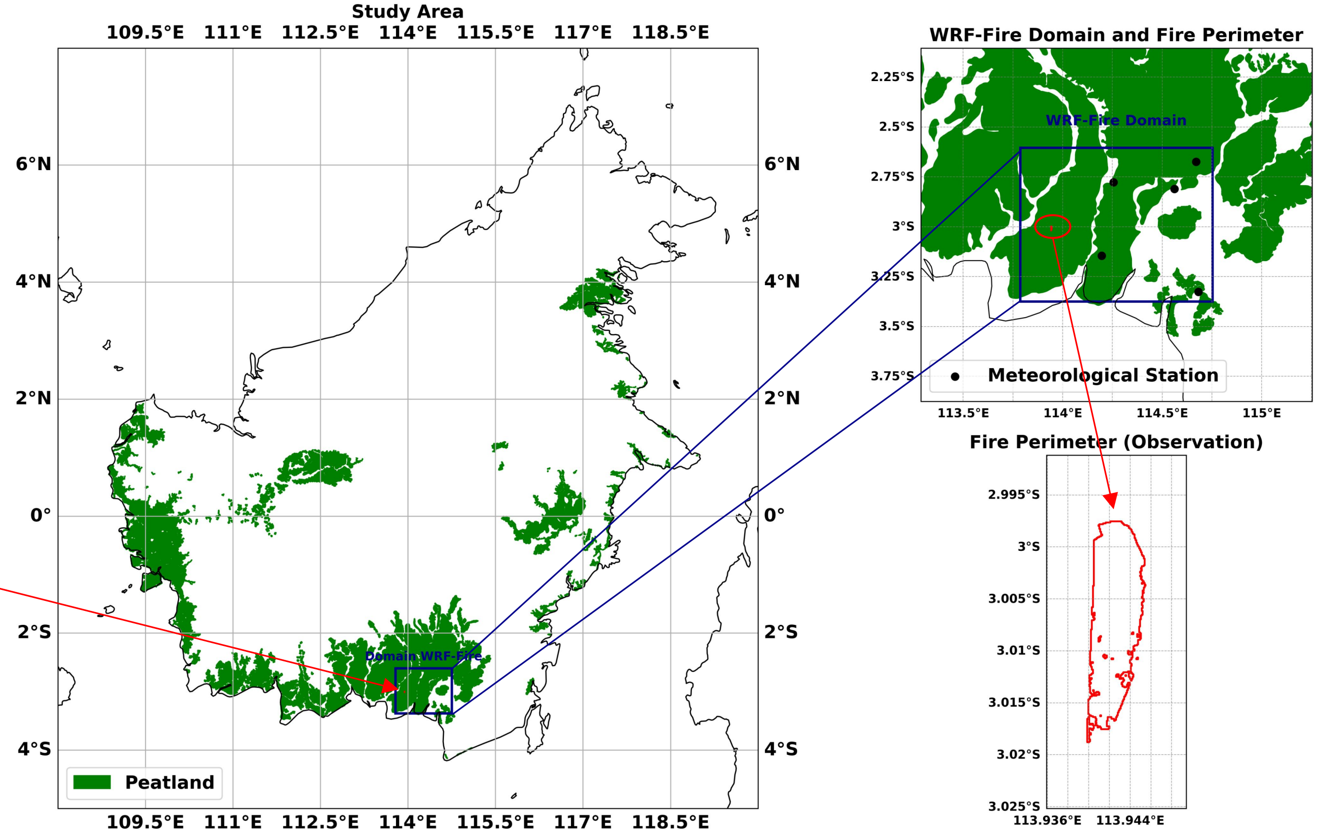
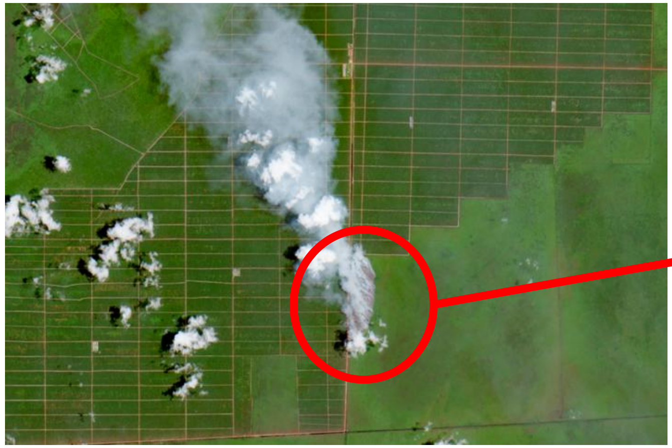
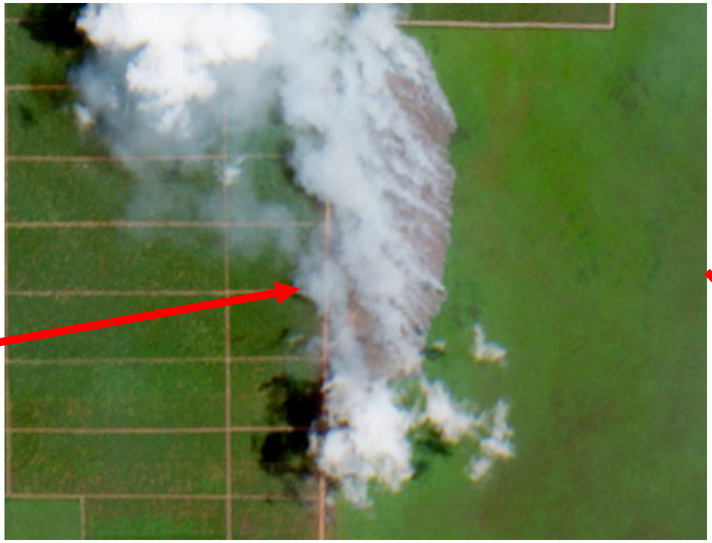


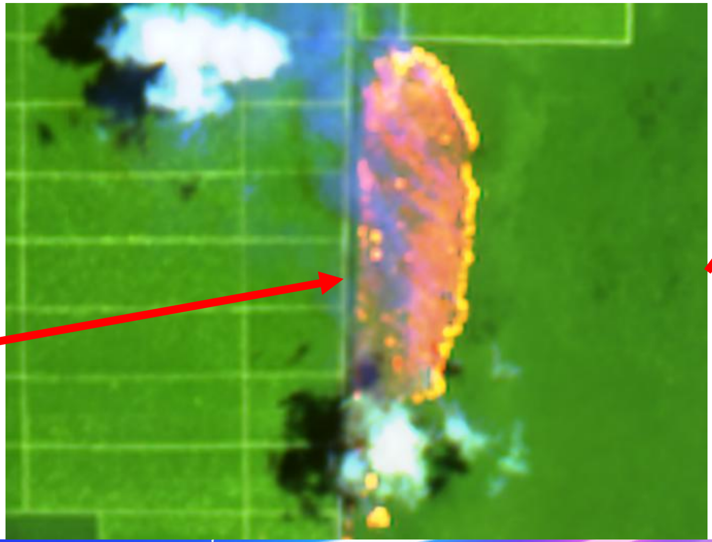
Fig. 2 Study Area and Ignition Point

True color (Band 4, 3, dan 2)





False color (Band 12, 11, dan 4)



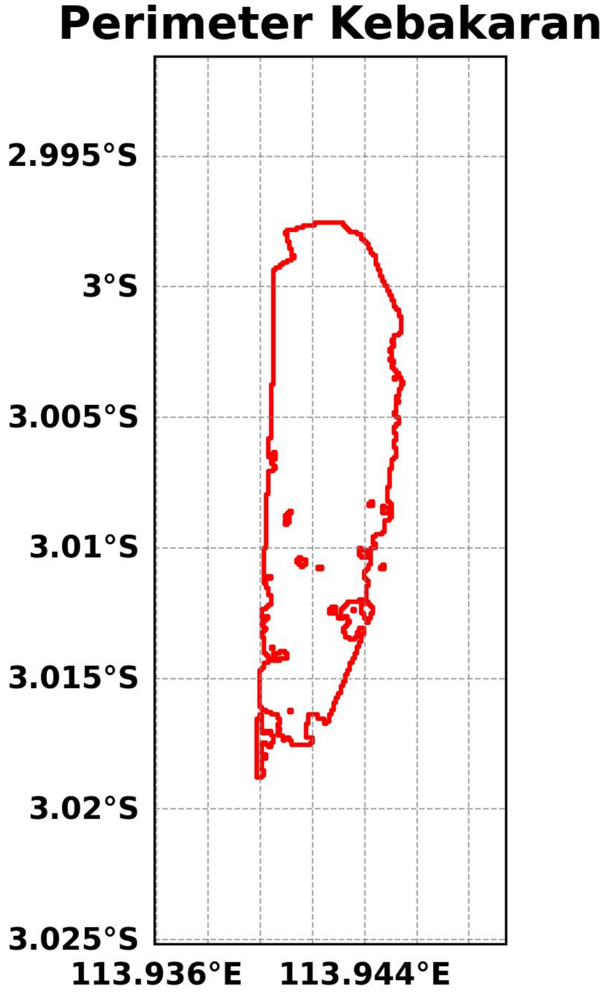


Fig. 3 Lokasi *Fire Ignition*

METHOD

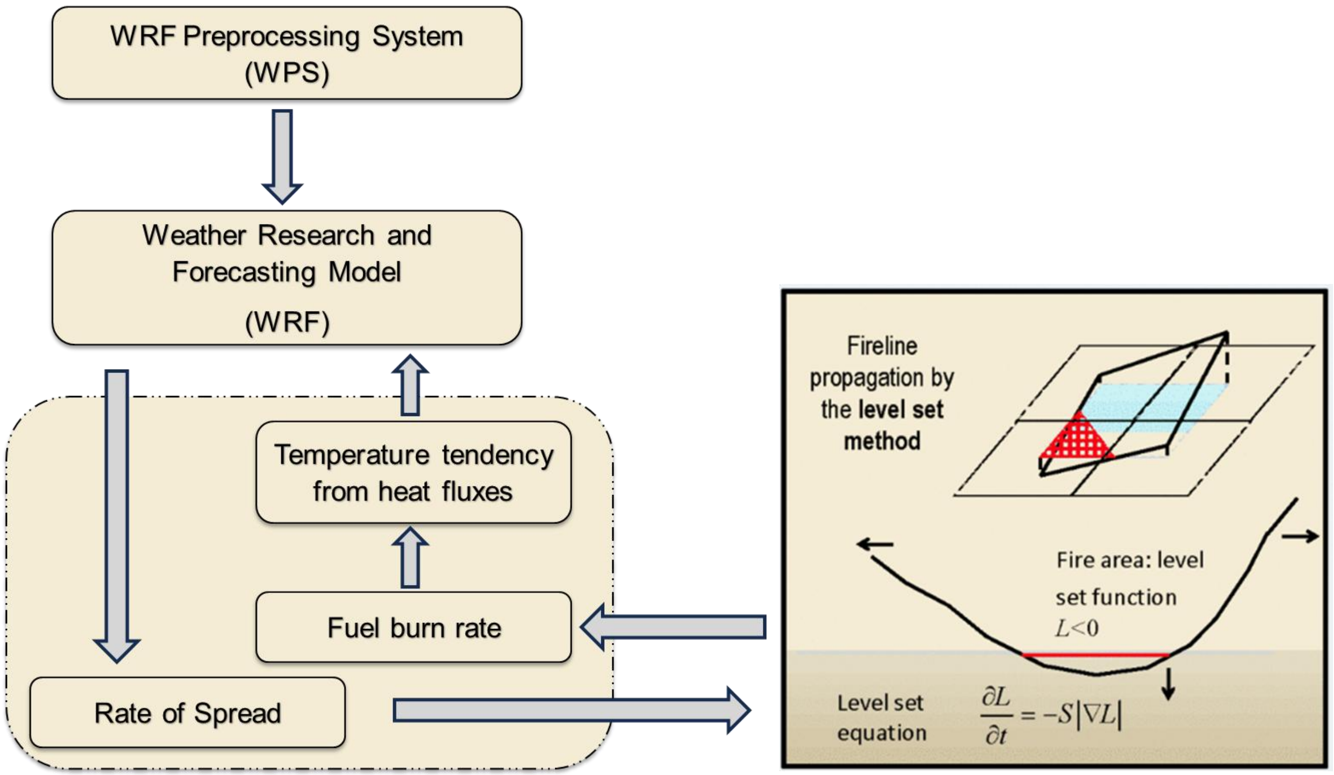


Fig. 4 *Weather Research and Forecasting – Fire* (WRF-Fire) Process

Run WRF-Fire Model

1 Domain with spatial resolution of 200m

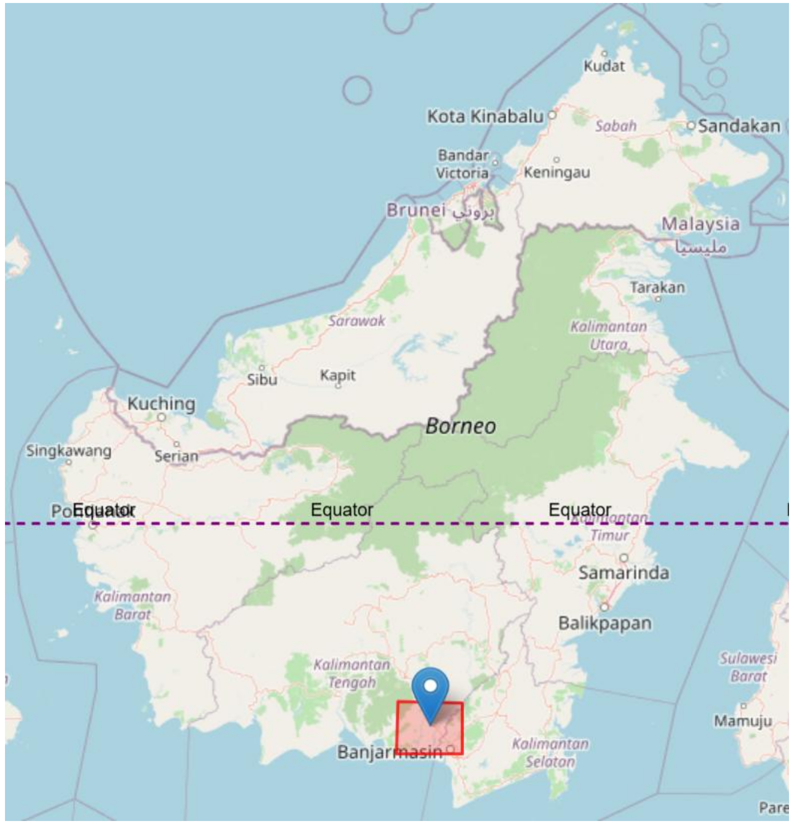


Fig. 5 WRF-Fire model domain

https://jiririchter.github.io/WRFDomainWizard/

WRF-Fire Model Performance

Fig. 6 Reliability analysis of meteorological variable

1. *Mean Absolute Error* (MAE)

$$MAE = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$$

2. *percent Bias* (pBias)

$$pBias = \left[\frac{\sum_{i=1}^{n} (x_i - y_i)^2 \times 100}{\sum_{i=1}^{n} x_i}\right]$$

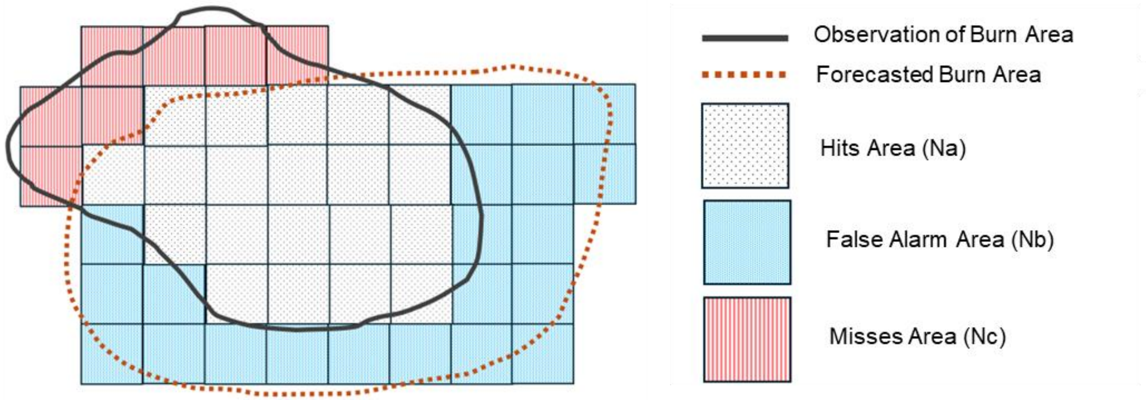


Fig. 7 Dichotomous Metrics for spatial performance analysis

1. *Probability of Detection* (POD) or *Hit Rate*

$$\mathrm{POD} = \frac{N_A}{N_A + N_C}$$

Forecast	Observation: Burn	Observation: Unburn
Burn	N_A	N_B
Unburn	N_C	N_D (Correct non-event)

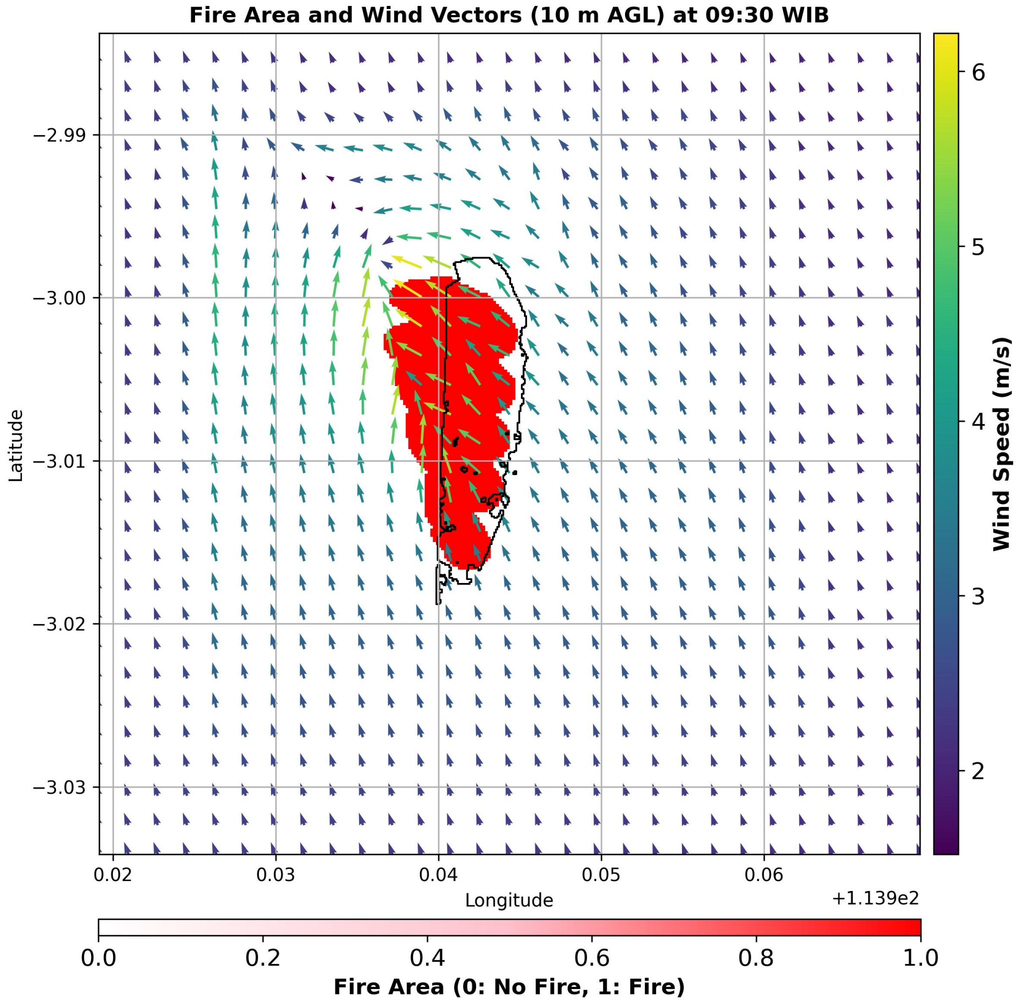
2. *Precision*

$$Precision = \frac{N_A}{N_A + N_B}$$

3. *F1-Score*

$$F1 - score = \frac{2N_A}{2N_A + N_B + N_c}$$

WRF-Fire Model Performance



RESULT

Total burned area from WRF-Fire

- 138.72 Ha

Total burned area from Sentinel-2p

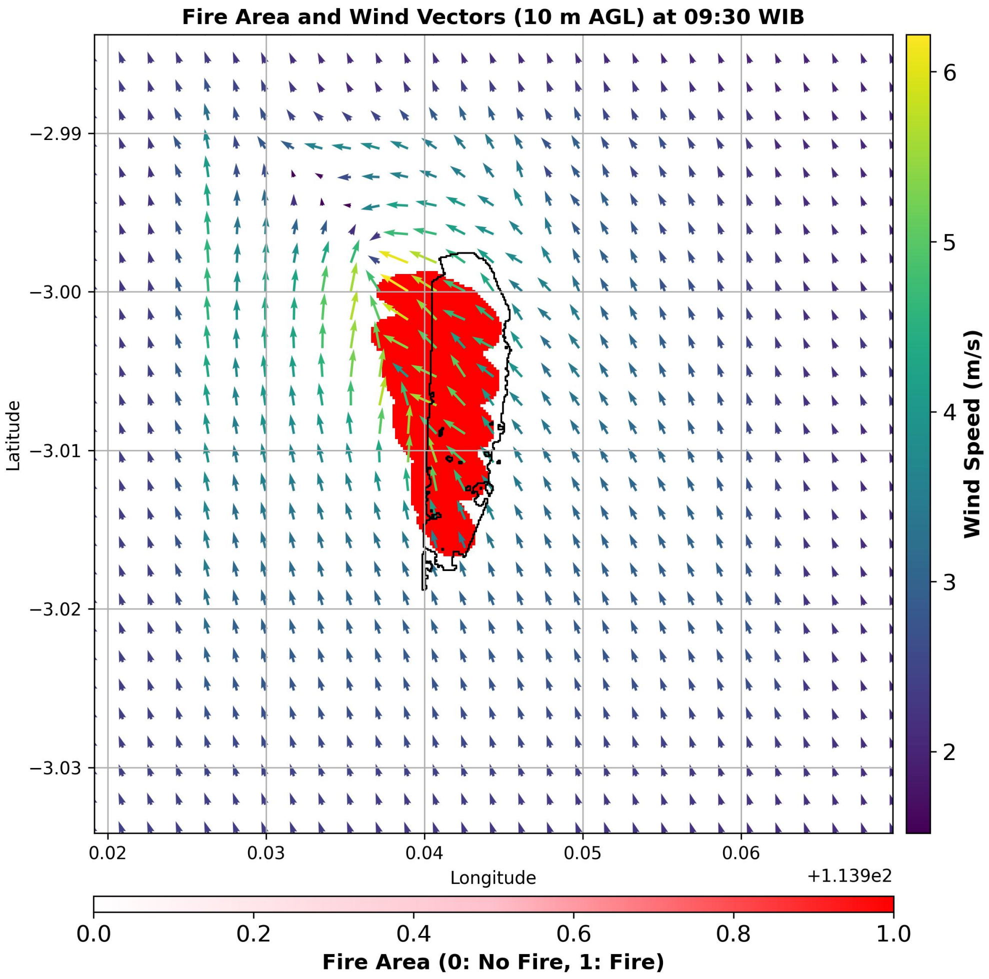
- 99.17 Ha

Dichotomous metrics

- POD (Hit Rate) = 77.27%
- Precision = 68.00%
- F1-Score = 72.34%

Fig. 8 Fire area, wind direction, and wind speed at 09:30 local time (WIB) based on WRF-Fire model output

WRF-Fire Model Performance



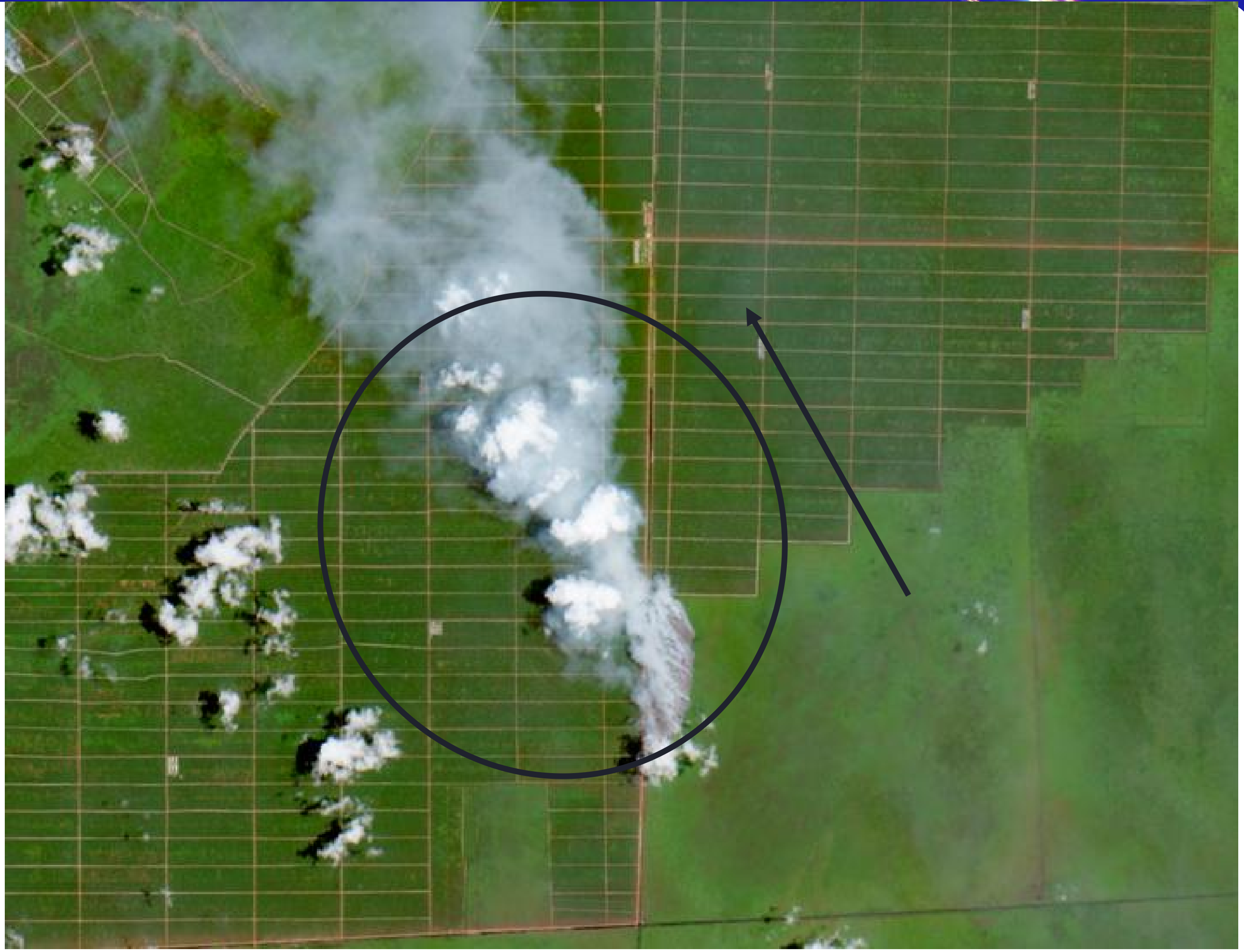


Fig. 9 Comparison between fire smoke direction and wind direction simulated by the WRF-Fire model

WRF-Fire Model Performance

Table 1. Observed (BMKG) and forecasted (WRF-Fire) meteorological variables from at 09:30 local time (WIB).

Automatic Weather Station	Rainfall (mm)		Wind Speed (m/s)		Wind Direction (°)		Temperature (°C)	
	Obs	Model	Obs	Model	Obs	Model	Obs	Model
Sungai Tabuk	0	0	2.00	2.37	162	161	31.86	31.10
Pulang Pisau	0	0	3.23	2.28	153	125	32.09	30.39
Dadahup	0	0	1.92	2.70	128	121	31.80	31.31
Kapuas Murung	0	0	2.20	2.05	134	123	30.71	30.76
Pandih	0	0	1.82	0.85	131	108	30.90	30.13

Rainfall
- MAE = 0 mm
- *pBias* = 0 %

Wind Speed
- MAE = 0.644 m/s
- *pBias* = -8.24%

Wind Direction
- MAE = 14°
- *pBias* = -9.89%

Temperature
- MAE = 0.754°C
- *pBias* = -2.33%

Forecast of Peatland Fire Propagation

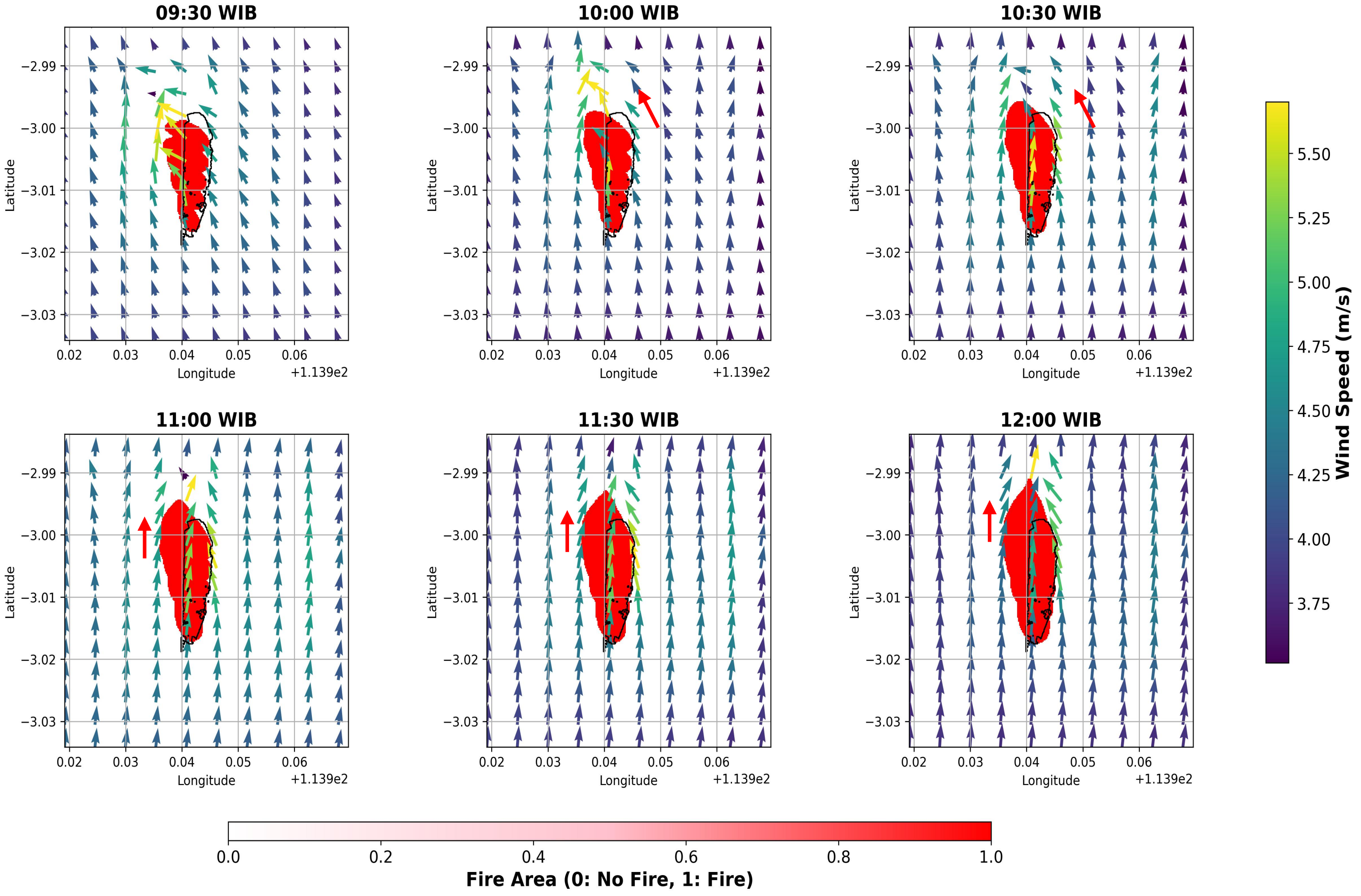


Fig. 10 Peatland fire propagation at 30-minute intervals.

WRF-Model limitation

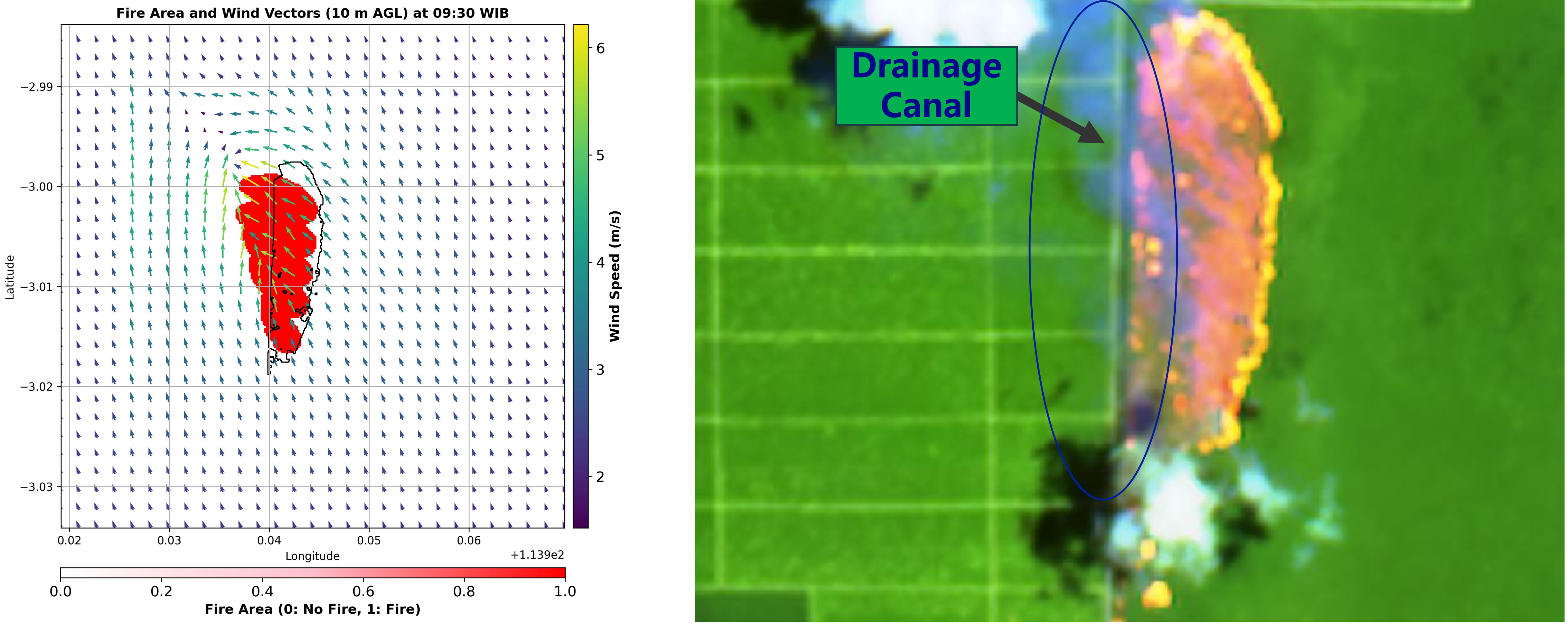


Fig. 11 Comparison between WRF-Fire model outputs and burn scars derived from Sentinel-2.

**The example of peatland fire on
19 Oktober 2023 – Henda (-2.572, 114.189)**

CONCLUSSIONS

- WRF-Fire model can predict the fire propagation with *F1-Score* = 72.34%.
- Meteorological variables output from WRF-Fire model is reliable with low *error* (MAE) dan bias (pBias).
- The most influential meteorological factors in predicting peatland fire propagation in Indonesia are wind speed and wind direction.

REFFERENCES

Anda M, Ritung S, Suryani E, Sukarman, Hikmat M, Yatno E, Mulyani A, Subandiono RE, Suratman, Husnain. 2021. Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. *Geoderma*. 402:115235.doi:10.1016/j.geoderma.2021.115235.

Harenda KM, Lamentowicz M, Samson M, Chojnicki BH. 2018. The Role of Peatlands and Their Carbon Storage Function in the Context of Climate Change. Di dalam: Zielinski T, Sagan I, Surosz W, editor. *Interdisciplinary Approaches for Sustainable Development Goals*. [internet] Cham. Cham: Springer International Publishing. (GeoPlanet: Earth and Planetary Sciences). hlm. 169–187.

Nelson K, Thompson D, Hopkinson C, Petrone R, Chasmer L. 2021. Peatland-fire interactions: A review of wildland fire feedbacks and interactions in Canadian boreal peatlands. *Science of The Total Environment*. 769:145212.doi:10.1016/j.scitotenv.2021.145212.

Lin S, Liu Y, Huang X. 2021. How to build a firebreak to stop smouldering peat fire: insights from a laboratory-scale study. *Int. J. Wildland Fire*. 30(6):454–461.

Thank You

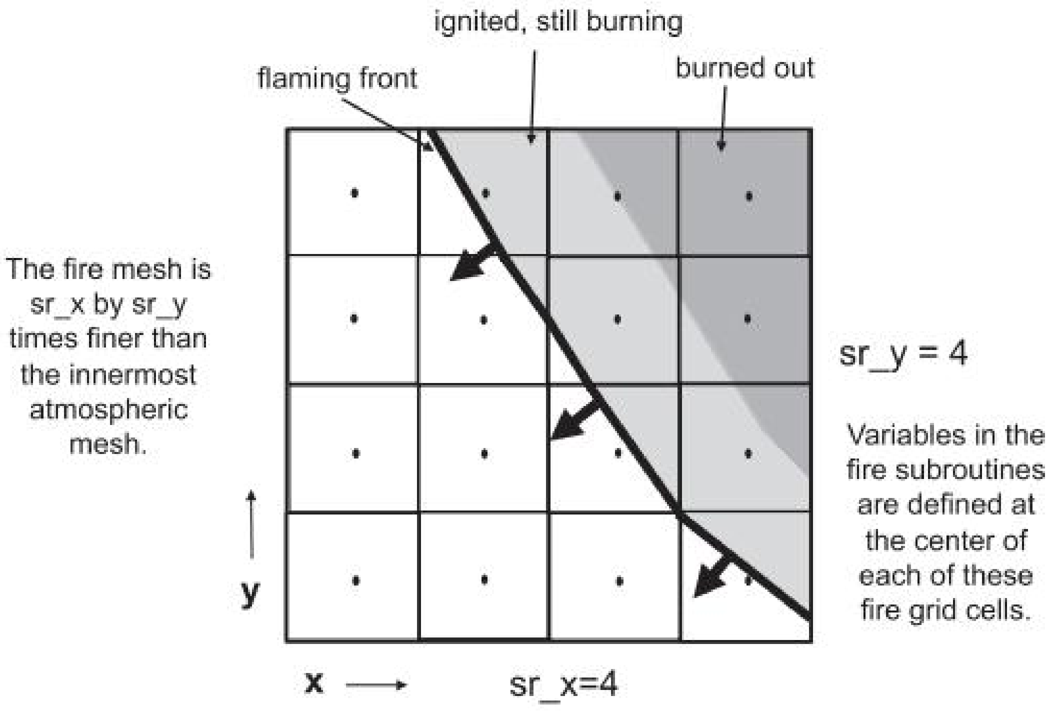


FIG. 2. Within each *x*–*y* atmospheric grid cell on the earth's surface is a further refined (sr_x in *x* and sr_y in *y*) mesh of fire grid cells. In this image, the fire mesh is 4 times as fine in both directions as the innermost atmospheric mesh.

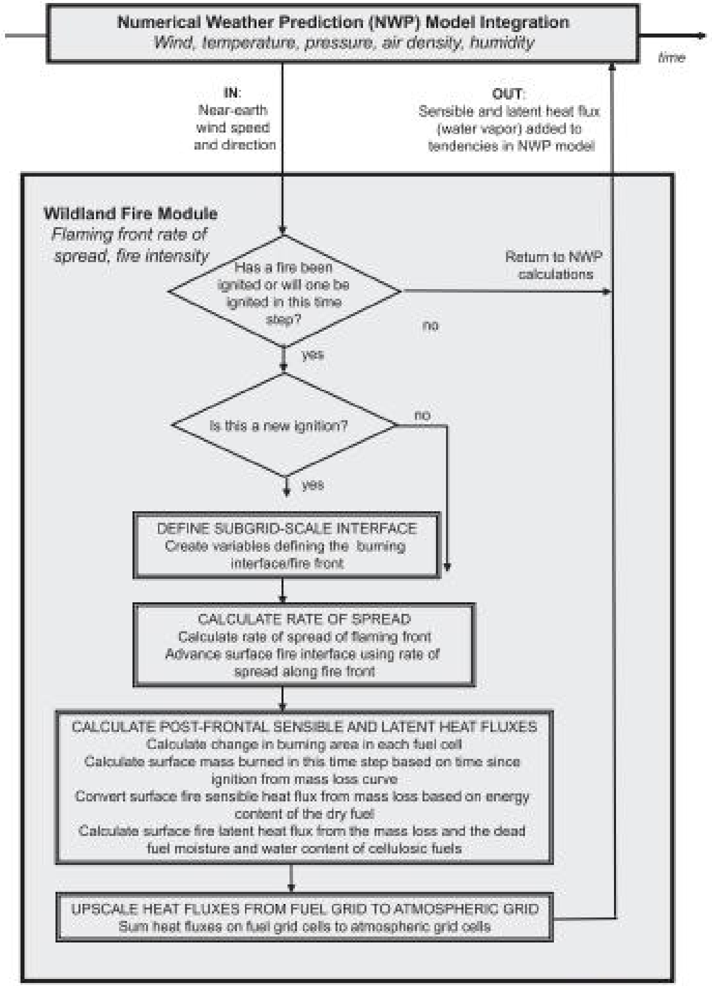
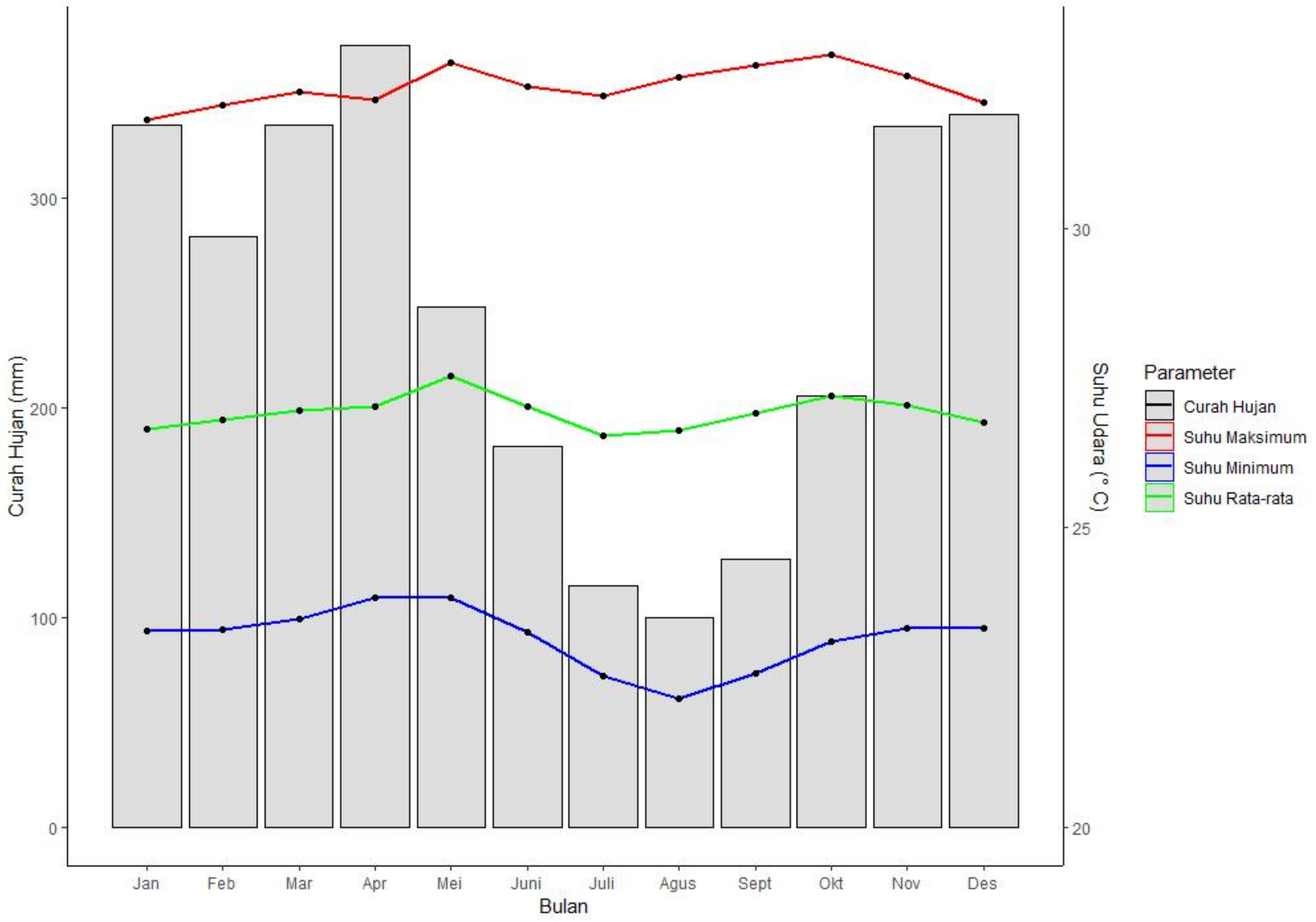


FIG. 1. The components of the WRF coupled weather–fire model.


Curah Hujan (mm)
0
100
200
300
Suhu Udara (° C)
20
25
30
Jan
Feb
Mar
Apr
Mei
Juni
Juli
Agus
Sept
Okt
Nov
Des
Bulan
Parameter
Curah Hujan
Suhu Maksimum
Suhu Minimum
Suhu Rata-rata

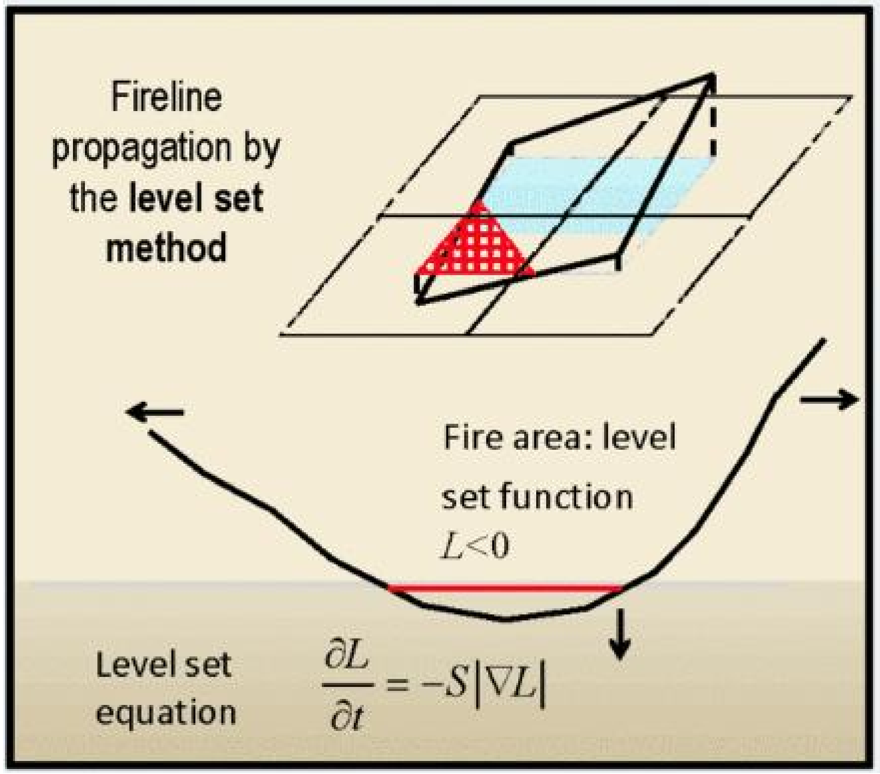
The level set method is a numerical technique used in computer simulations to track the evolution of interfaces and shapes over time. In the context of fire modeling, fireline propagation using the level set method involves representing the advancing front of a fire using a level set function.

1. Level Set Method:

- The level set method represents a propagating interface (such as a fire front) as the zero level set of a higher-dimensional function.
- The zero level set corresponds to the actual interface, and the evolution of this level set function helps track the movement of the interface over time.

2. Fireline Propagation:

- In the context of wildfires or fire modeling, fireline propagation refers to the spread of the fire front or the advancing edge of the fire.
- The level set method allows for the dynamic tracking of this fireline by updating the level set function as the fire progresses.



Characteristics of the Anderson’s 13 surface fuel models used in the Community Fire Behavior model (CFBM)

Fuel model name	Fuel load [$kg\,m^{-2}$]	Fuel bed depth [m]	Moisture of extinction [–]	Surface area to volume ratio [$feet^{-1}$]	burn time [s]
1. Short grass	0.166	0.305	0.12	3500	7
2. Timber (grass and understory)	0.896	0.305	0.15	2784	7
3. Tall grass	0.674	0.762	0.25	1500	7
4. Chaparral	3.591	1.829	0.20	1739	180
5. Bush	0.784	0.610	0.20	1683	100
6. Dominant bush, hardwood slash	1.344	0.762	0.25	1564	100
7. Southern rough	1.091	0.762	0.40	1562	100
8. Closed timber litter	1.120	0.061	0.30	1889	900
9. Hardwood litter	0.780	0.061	0.25	2484	900
10. Timber (litter and understory)	2.692	0.305	0.25	1764	900
11. Light logging slash	2.582	0.305	0.15	1182	900
12. Medium logging slash	7.749	0.701	0.20	1145	900
13. Heavy logging slash	13.024	0.914	0.25	1159	900

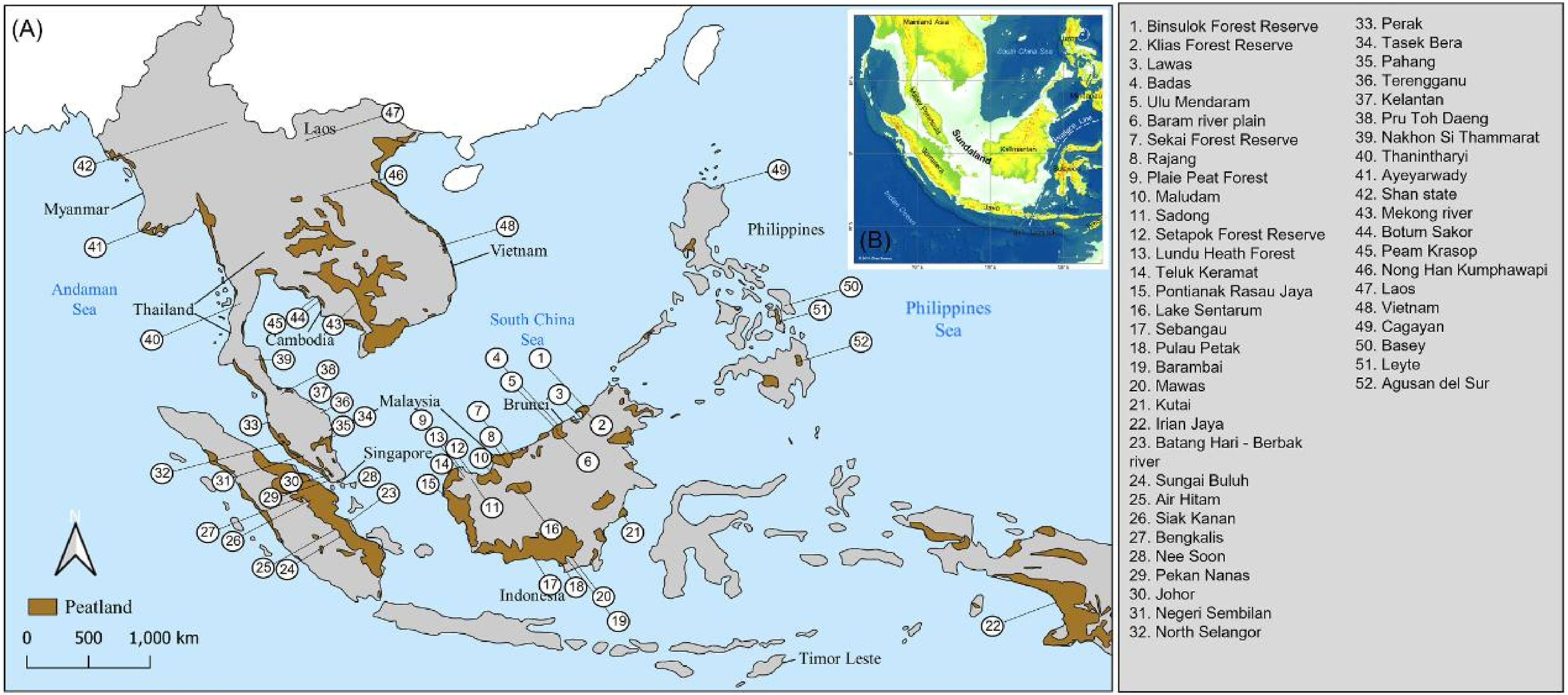


Fig. 1. Distribution of peatlands in the Southeast Asia region and the approximate locations of the 52 sites, which are reviewed in this paper (modified after Dohong et al., 2017; Yu et al., 2010). Inset shows the region of Sundaland (after Irwanto, 2019).