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Spatial influence of agricultural residue burning and aerosols on land surface temperature

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Table S1. Summary of geospatial data used for the analysis.

Core datasets	Resolution	Version	Quality assurance	Time period
VIIRS/SNPP Active fire count	375 m	VNP14IMG, Collection-2 Level-2	Fire mask class 8 and 9	October to November, 2017-2021
VIIRS/SNPP Fire radiative power (FRP)	375 m	VNP14IMG, Collection-2 Level-2	-	October to November, 2017-2021
MODIS/Aqua daytime Land surface temperature (LST)	1 km	MYD11A1 Version 6.1	Quality flag '00'	September to November, 2017-2021
VIIRS/SNPP Aerosol optical depth (AOD) at 550 nm	6 km (at nadir)	AERDB_L2_VIIRS_SNPP Level-2, Version 1 Deep Blue AOD	QA ≥ 2	September to November, 2017-2021
MODIS/ Terra+Aqua Land cover type	0.5 km	MCD12Q1 Level-3, Version 6.1	land cover type 12	For year 2017
SMAP Surface and root-zone soil moisture	9 km	SMAP L3_SM_P Enhanced L3 Radiometer EASE-Grid Soil Moisture Version 6	Research-quality data '0'	October to November, 2017-2021
VIIRS/SNPP Normalized Difference Vegetation Index (NDVI)	6 km	AERDB_L2_VIIRS_SNPP Level-2, Version 1 TOA_NDVI Deep Blue NDVI	-	October to November, 2017-2021
MODIS/Terra+Aqua Albedo	500 m	MCD43A3 Albedo_WSA_shortwave BRDF/Albedo Daily L3 version 6.1	0 = good quality	October to November, 2017-2021
Copernicus DEM Elevation	30 m	GLO-30	-	For year 2015
ECMWF AgERA5 Surface meteorological data (At, SR, RH and PT)	0.1° x 0.1°	ERA 5 Version 2.0	-	October to November, 2017-2021
ECMWF ERA5 Planetary boundary layer height (PBLH)	0.25° x 0.25°	for 13:00-14:00 h local time	-	October to November, 2017-2021

NOTE. LST and AOD data were retrieved additionally for September, 2017 to 2021 to estimate climatological mean.

Table S2. Year-wise area of the selected intensive fire zone.

Year	Area (Sq. km)
2017	32433.66
2018	30658.67
2019	27403.99
2020	33374.95
2021	35938.03

NOTE. The area indicates the region selected as year-wise intensive fire zone for retrieval and processing all independent and dependent variables.

Table S3. Selection of *timeframe* for assessing FRP-AOD-LST association for scenario 1.

a. Selection of initial date for scenario 1 window during October

	Day (-1)	Start Day	Day (+1)	Day (+2)	Day (+3)	Day (+4)
2017	13/10/2017	14/10/2017	15/10/2017	16/10/2017	17/10/2017	18/10/2017
	1678.45 (+13%)	2522.82 (+50%)	3359.19 (+33%)	2204.92 (-34%)	3695.82 (+67%)	4329.95 (+17%)
2018	18/10/2018	19/10/2018	20/10/2018	21/10/2018	22/10/2018	23/10/2018
	1445.37 (+22%)	1691.90 (+17%)	2595.33 (+53%)	3216.01 (+23%)	3104.38 (-3%)	3931.42 (+26%)
2019	19/10/2019	20/10/2019	21/10/2019	22/10/2019	23/10/2019	24/10/2019
	1018.48 (+483%)	2209.16 (+116%)	2743.40 (+24%)	2383.29 (-13%)	3410.25 (+43%)	5198.44 (+52%)
2020	13/10/2020	14/10/2020	15/10/2020	16/10/2020	17/10/2020	18/10/2020
	1103.68 (-3.33%)	1971.18 (+78%)	2954.47 (+49%)	3014.95 (+2%)	4092.78 (+35%)	4736.94 (+15%)
2021	14/10/2021	15/10/2021	16/10/2021	17/10/2021	18/10/2021	19/10/2021
	1246.49 (+64.91%)	2448.76 (+96%)	2283.20 (-6%)	52.84 (-97%)	489.59 (+826%)	2919.01 (+496%)

b. Selection of end date for scenario 1 window during November

	Day (-4)	Day (-3)	Day (-2)	Day (-1)	End Day	Day (+1)
2017	05/11/2017	06/11/2017	07/11/2017	08/11/2017	09/11/2017	10/11/2017
	9201.01 (-67%)	468.63 (-94%)	2392.36 (+410%)	11117.41 (+364%)	4637.93 (-58%)	7340.48 (+58%)
2018	05/11/2018	06/11/2018	07/11/2018	08/11/2018	09/11/2018	10/11/2018
	19991.52 (+250%)	26829.78 (+34%)	26039.96 (-2%)	25544.46 (-2%)	11772.71 (-54%)	8881.65 (-25%)
2019	03/11/2019	04/11/2019	05/11/2019	06/11/2019	07/11/2019	08/11/2019
	13909.38 *No previous day FRP*	34052.03 (+144%)	28821.18 (-15%)	30376.77 (+5%)	982.62 (-97%)	2600.87 (+164%)
2020	10/11/2020	11/11/2020	12/11/2020	13/11/2020	14/11/2020	15/11/2020
	24637.64 (+119%)	20058.38 (-18%)	12780.17 (-36%)	10412.35 (-19%)	2061.06 (-80%)	334.66 (-83%)
2021	13/11/2021	14/11/2021	15/11/2021	16/11/2021	17/11/2021	18/11/2021
	34296.76 (+11%)	23066.75 (-32%)	16233.17 (-29%)	10931.80 (-33%)	4842.95 (-56%)	5259.44 (+8%)

Table S4. Descriptive statistics during two selected fire intensity scenarios.

	FRP	AOD	LST	SR	PR	RH	AT	PBLH	NDVI	SM	Albedo
Scenario 1											
2017 [2017-10-14 to 2017-11-09]	2,39,197.38	1.05	30.91	1,60,06,825.19	0.02	59.37	23.28	56.08	0.28	0.19	5.86
2018 [2018-10-19 to 2018-11-09]	2,67,352.65	0.89	30.27	1,57,61,927.68	0.22	57.7	21.64	69.93	0.31	0.19	0.25
2019 [2019-10-20 to 2019-11-07]	1,99,252.05	0.79	31.09	1,49,26,739.21	1.04	61.34	22.98	81.42	0.24	0.22	0.27
2020 [2020-10-14 to 2020-11-14]	4,59,783.90	0.85	31.55	1,61,87,920.97	0	52.07	21.51	45.21	0.25	0.21	0.61
2021 [2021-10-15 to 2021-11-17]	5,43,407.67	0.8	30.34	1,51,87,415.18	0.24	62.84	21.94	73.15	0.23	0.19	0.85
Scenario 2											
2017 [2017-11-01 to 2017-11-07], r=0.77, p=0.072	75,448.03	1.53	30.3	1,43,13,589.43	0.01	71.86	20.9	55.05	0.07	0.18	15.05
2018 [2018-10-30 to 2018-11-09], r=0.48, p=0.280	1,98,591.01	1.19	30	1,47,96,390.88	0.41	59.99	20.61	76.80	0.19	0.19	0.31
2019 [2019-10-26 to 2019-11-07], r=0.66, p=0.051	1,75,645.94	0.88	30.97	1,42,27,474.00	1.48	63.7	22.62	84.82	0.17	0.21	0.31
2020 [2020-11-01 to 2020-11-06], r=0.71, p=0.116	1,63,623.50	0.9	31.12	1,57,69,817.81	0	51.12	20.08	43.00	0.15	0.19	0.33
2021 [2021-10-24 to 2021-11-07], r=0.58, p=0.037	2,56,742.06	0.8	29.19	1,53,63,593.32	0.01	63.26	22.03	68.92	0.24	0.21	0.20

NOTE. FRP- Fire radiative power (MW), AOD- Aerosol optical depth, LST- Land surface temperature (°C), SR- Solar radiation ($J.m^{-2}day^{-1}$), PR- Precipitation ($mm\ day^{-1}$), RH- Relative humidity (%), AT-Ambient temperature (°C), PBLH- Planetary Boundary Layer Height (m, during 13:00-14:00 h local time); NDVI- Normalized Difference Vegetation Index; SM-Soil Moisture ($m^3\ m^{-3}$). FRP indicates spatial sum while other parameters indicate spatial average.

For scenario 2, high and positive correlation criteria between FRP and LST was considered to select temporal window.

Table S5. Variations in monthly FRP aggregate, mean AOD and mean LST over extended geographical region for year 2017 to 2021.

		FRP (MW)				AOD				LST (C)			
		FRP (sum)	**Min**	**Max**	**St Dev**	**AOD**	**Min**	**Max**	**St Dev**	**LST**	**Min**	**Max**	**St Dev**
2017	Oct	199333	303	22088	6487	0.68	0.32	1.39	0.26	32.02	29.95	33.91	1.21
	Nov	200242	98	30760	7119	0.98	0.40	1.58	0.36	28.70	20.40	31.50	2.74
	Oct. to Nov.	399575	98	30760	6749	0.83	0.32	1.58	0.35	30.47	20.40	33.91	2.65
2018	Oct	128657	12	18519	5282	0.59	0.35	1.16	0.20	30.18	26.95	32.42	1.48
	Nov	298093	225	30363	9731	0.78	0.28	1.51	0.34	30.55	24.32	33.67	2.07
	Oct. to Nov.	426750	12	30363	8286	0.68	0.28	1.51	0.29	30.36	24.32	33.67	1.78
2019	Oct	134642	5	25240	6239	0.70	0.31	1.30	0.26	30.58	25.13	32.36	1.73
	Nov	198923	2	37977	10780	0.69	0.33	1.43	0.29	28.18	23.53	32.60	3.29
	Oct. to Nov.	333565	2	37977	8775	0.70	0.31	1.43	0.27	29.50	23.53	32.60	2.80
2020	Oct	200407	581	32131	7442	0.51	0.27	1.12	0.20	32.43	30.18	34.31	1.17
	Nov	334532	87	35180	12722	0.79	0.33	1.95	0.37	28.85	22.52	32.93	2.99
	Oct. to Nov.	534939	87	35180	10560	0.65	0.27	1.95	0.33	30.83	22.52	34.31	2.80
2021	Oct.	100039	6	17701	4389	0.49	0.32	1.60	0.23	30.32	24.55	34.41	2.26
	Nov.	519148	70	44273	16564	0.84	0.44	1.31	0.26	30.63	28.88	31.76	0.74
	Oct. to Nov.	619187	6	44273	13878	0.67	0.32	1.60	0.30	30.47	24.55	34.41	1.67

Table S6. Details of Random Forest hyper-parameter tuning by Bayesian optimization.

Hyper-parameter	Search Space	Scenario 1	Scenario 2
n_estimators	(50 – 500)	55	417
max_depth	(3 – 15)	7	15
min_samples_split	(2 – 10)	7	2
min_samples_leaf	(3 – 15)	3	3
max_features	(0.5 to 0.6, 'sqrt', 'log2')	0.52	0.56

Note: Random Forest hyper parameter tuning was made by Bayesian optimization technique (BayesSearchCV, 3-fold GroupKFold CV, n_iter = 60).

Table S7. Global Moran's I Summary for LST across intensive fire zone for year 2017-2021.

Moran's Index	0.225
Expected Index	-0.000
Variance	0.000
z-score	414.448
p-value	0.000

Table S8. GWR simulation criteria and model performance evaluation.

Statistic / Parameter	Scenario 1	Scenario 2
Kernel type	Adaptive Bisquare	Adaptive Bisquare
Bandwidth type	Adaptive	Adaptive
Distance metric	Euclidean	Euclidean
Bandwidth used	95.00	108.00
Global R^2	0.7636	0.7405
Adjusted R^2	0.7077	0.6867
Mean residual	-0.0010	0.0057
Std residual	0.4862	0.5094
Min residual	-2.7031	-3.1648
Max residual	3.7631	2.1994
AIC	5641.3899	5787.3834
AICC	5929.4947	6012.8873
BIC	9322.4082	9073.3852
Intercept (Mean ± SD)	0.0600 ± 3.0489	-0.5049 ± 2.1422
coef_Pr (Mean ± SD)	0.1723± 4.2826	-0.1778 ± 2.2718
coef_FRP (Mean ± SD)	0.0897 ± 0.2980	0.0825 ± 0.2582
coef_AOD (Mean ± SD)	-0.0703 ± 0.7132	0.0437 ± 0.6714
coef_PBLH (Mean ± SD)	-0.0514 ± 1.4283	-0.3153 ± 1.8449
coef_NDVI (Mean ± SD)	-0.7567 ± 1.0860	-0.6459 ± 0.9541
coef_RH (Mean ± SD)	-0.0881 ± 3.6078	-0.1015 ± 3.2925
coef_AT (Mean ± SD)	-0.0742 ± 3.5137	-0.1774 ± 3.0913
coef_Elev (Mean ± SD)	-0.0580 ± 1.5147	-0.2108 ± 1.5434
coef_Albedo (Mean ± SD)	0.2300 ± 0.2738	0.0772 ± 0.2128

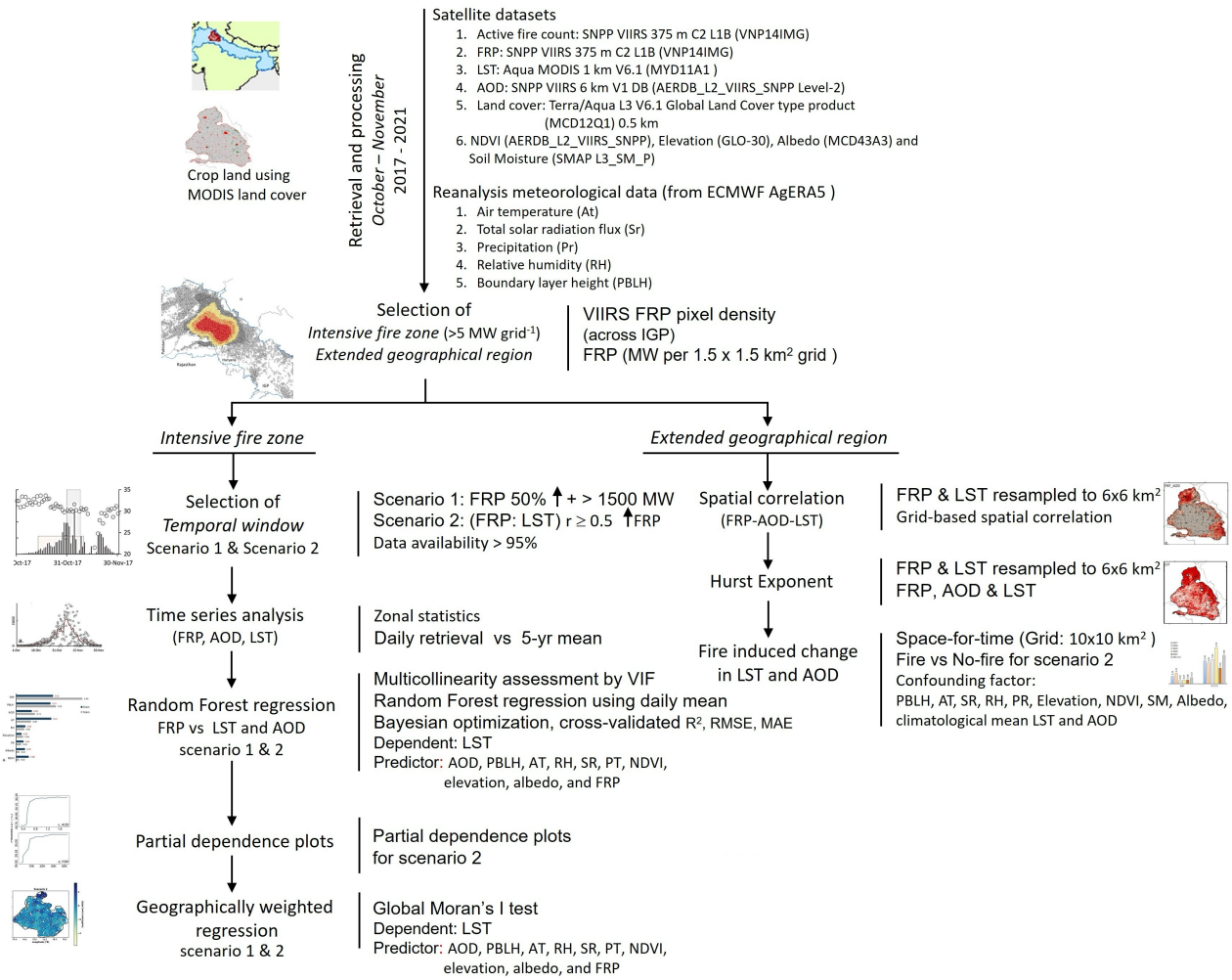


Fig. S1. Schematic workflow indicating core datasets and adopted methodology for exploring FRP-AOD-LST association.

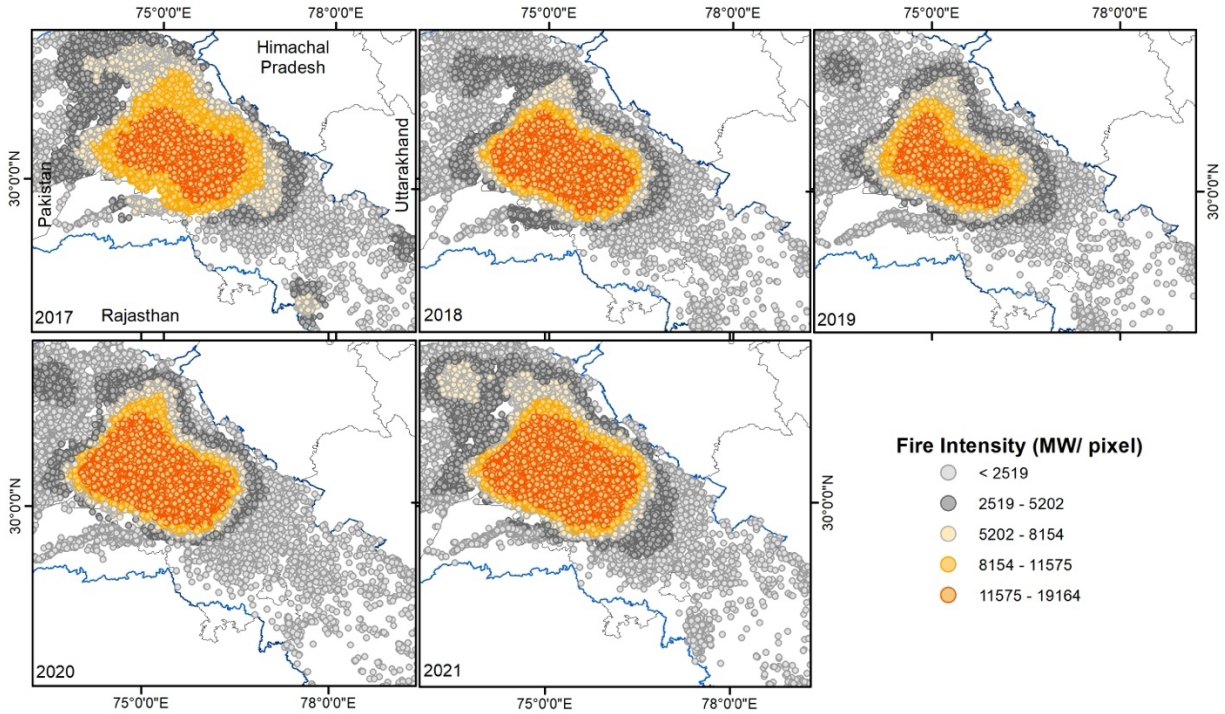


Fig. S2. Spatial variations in VIIRS FRP intensity across the northwest India during 2017 to 2021.

NOTE. The pixel size is VIIRS VNP14IMG 375x375 m^2.

Fire intensity is measured as fire radiative power in MW per pixel (375x375 m2) while fire density is measured as fire radiative power in MW per square grid per day (2.25 Km^{-2} day^{-1}).

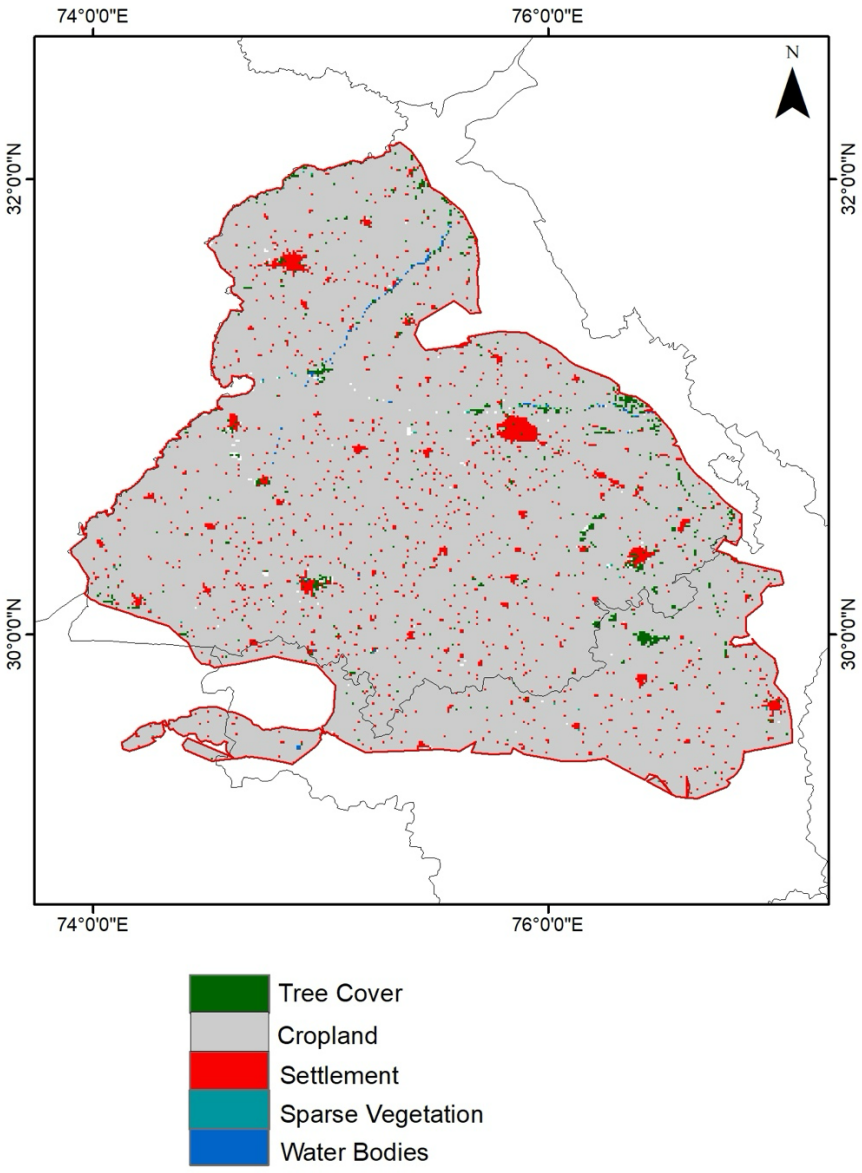


Fig. S3. Terra/Aqua MODIS land use land cover classification map of year 2017 over the extended geographical region in northwest India.

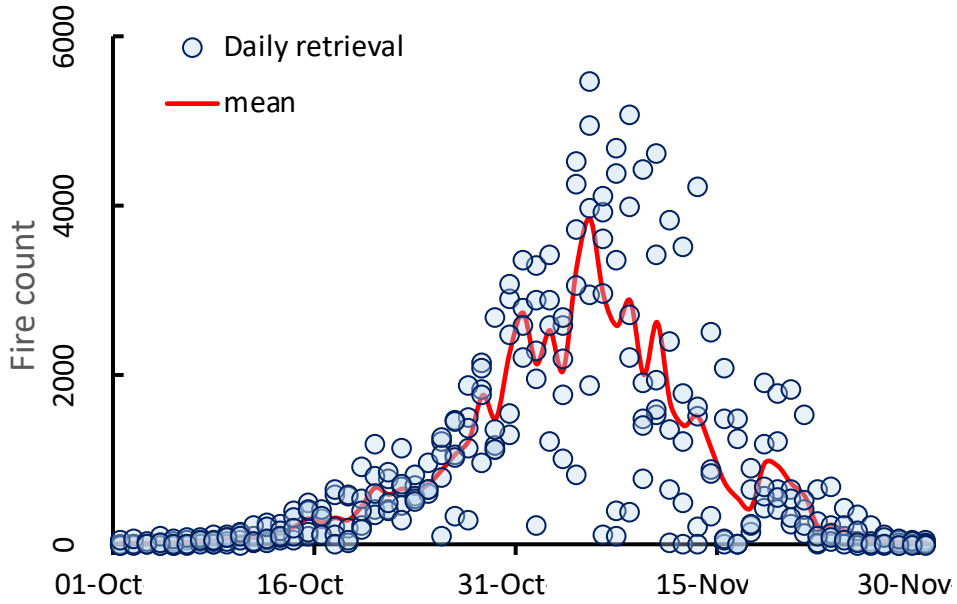
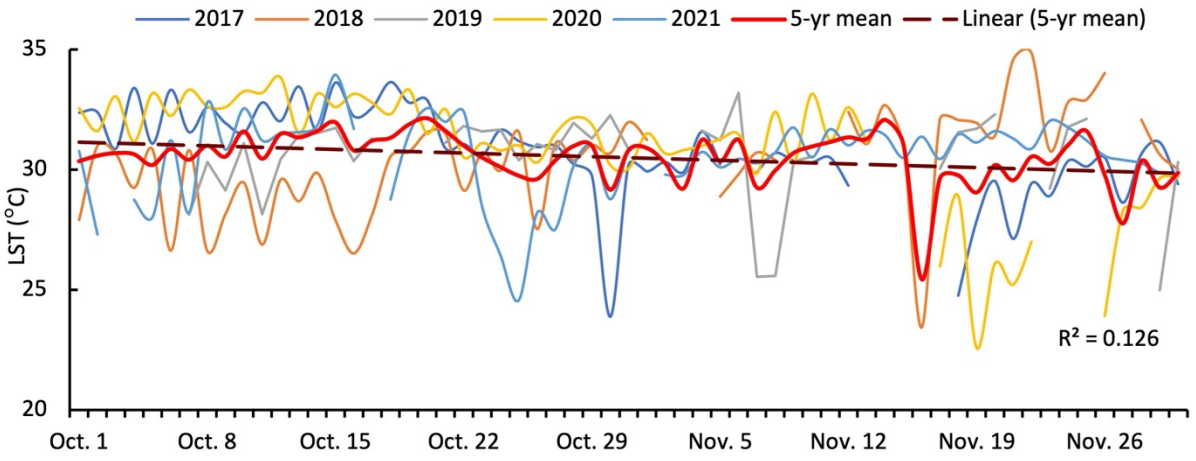


Fig. S4. Time series of five-year mean fire count against daily retrievals over intensive fire zone.



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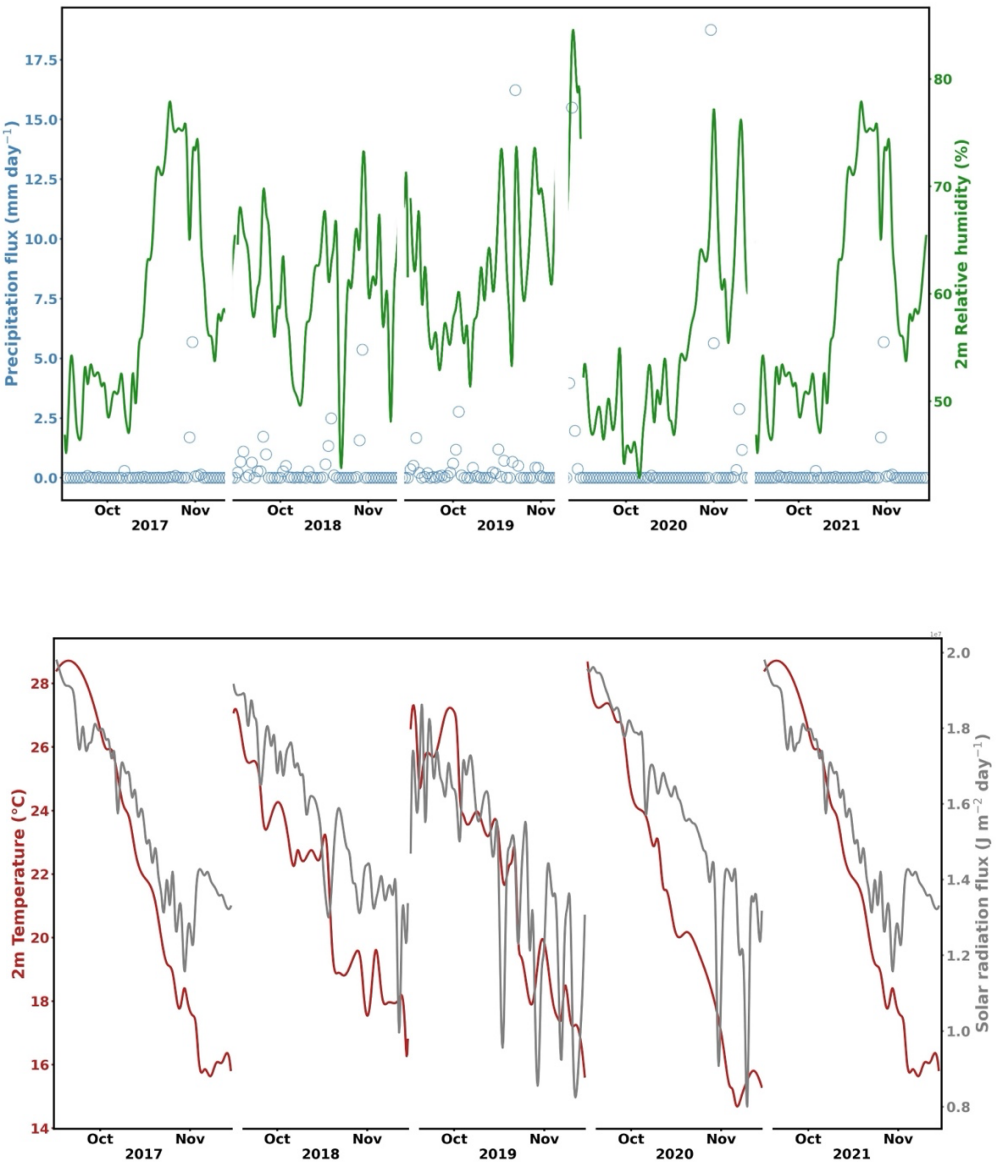
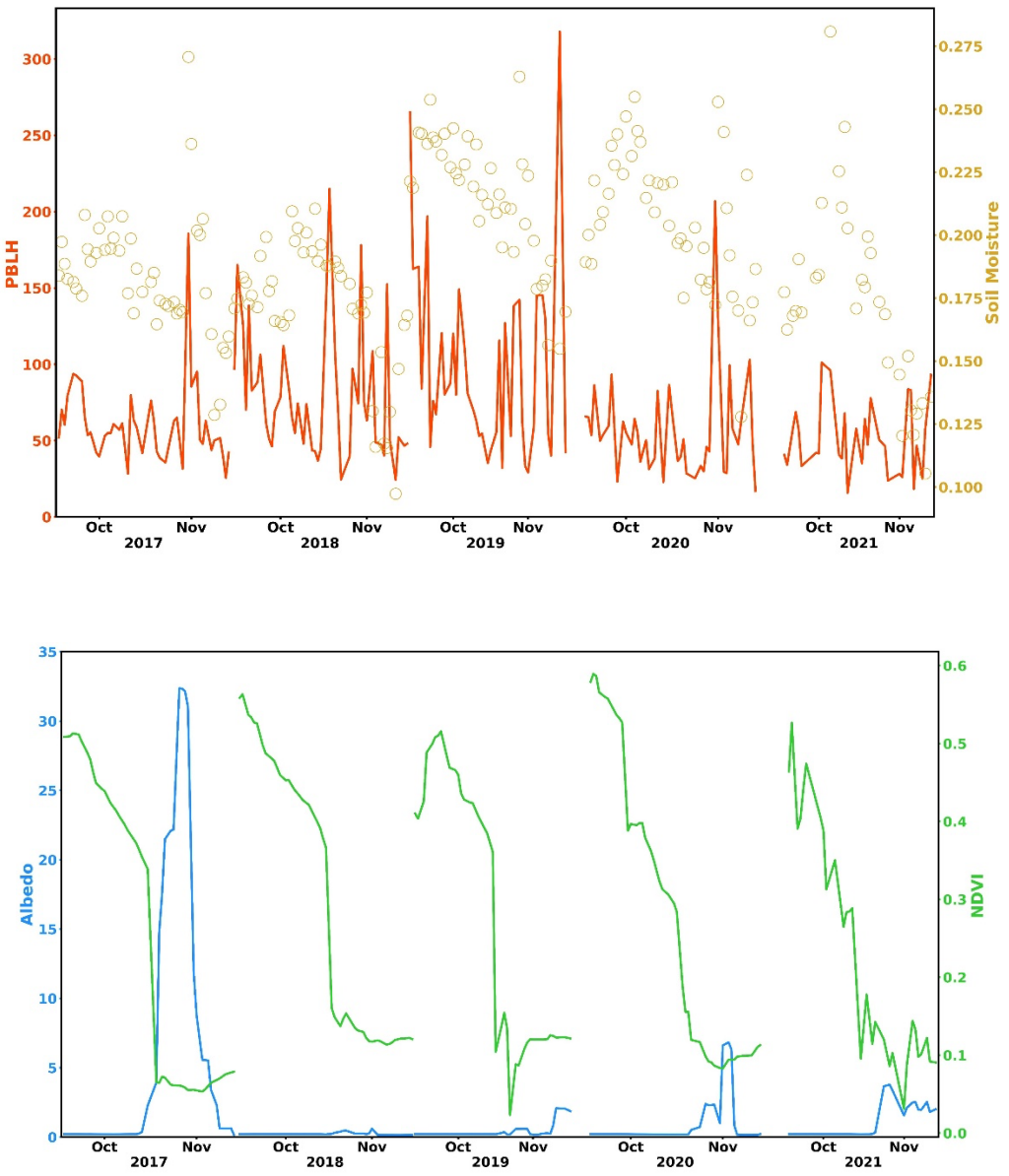


Fig. S6. Time series of predictor variables over crop residue-based fire zone. (*continue*)



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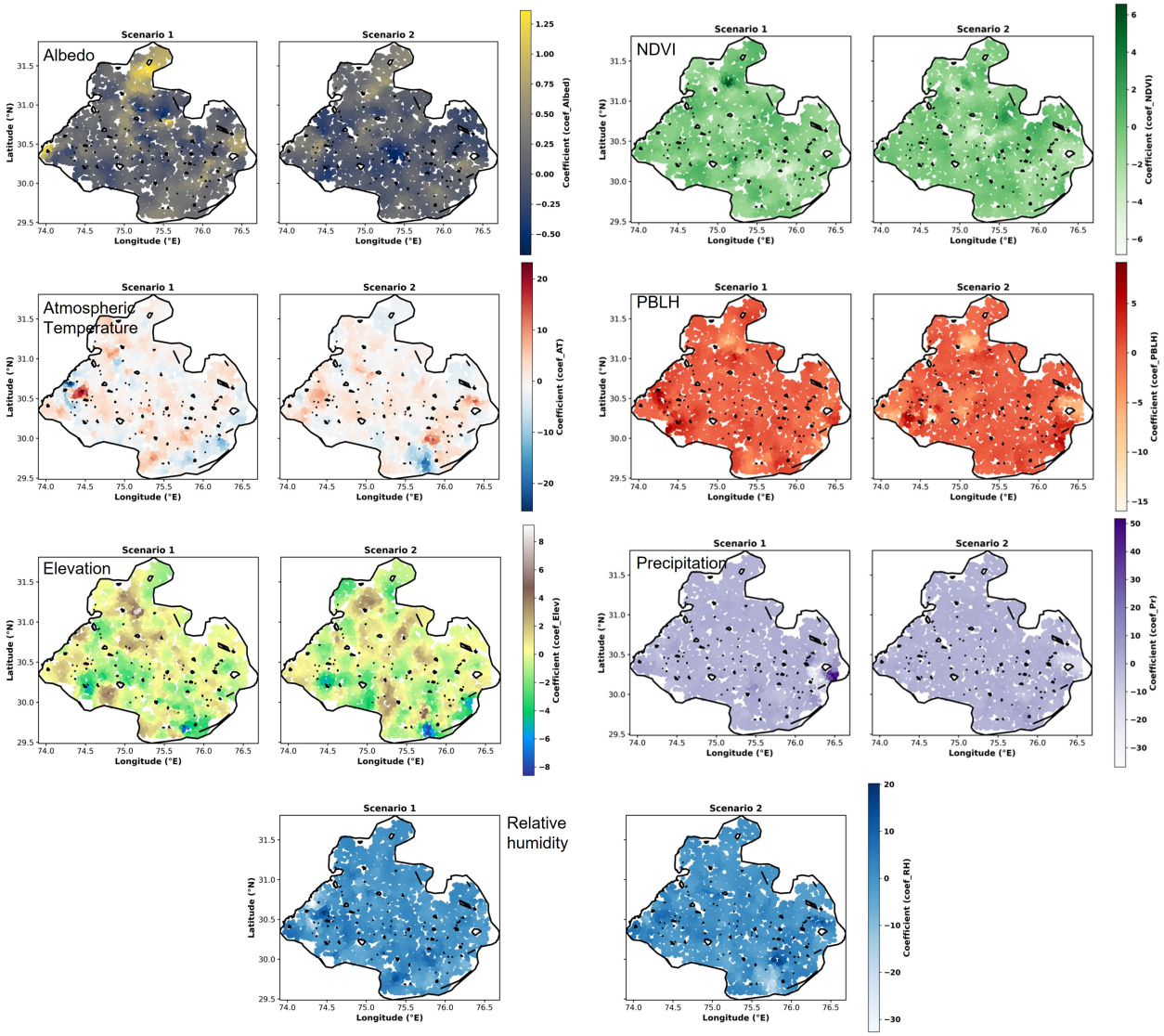
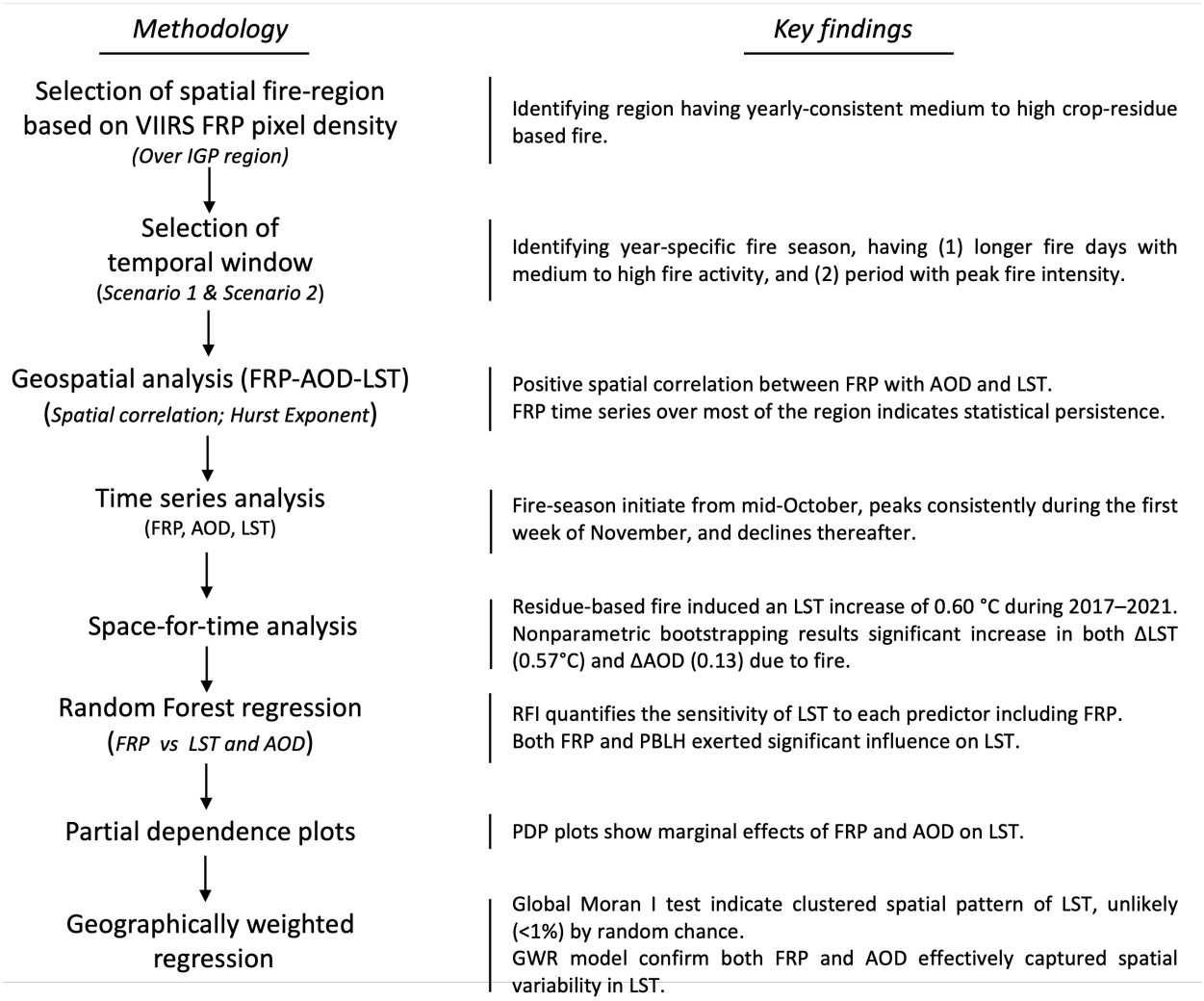


Fig. S7. Spatial distribution of FRP and AOD GWR coefficients across intensive fire zone.



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