Vegetation Fires in South/Southeast Asia and Emissions during COVID-19 and Pre-Pandemic

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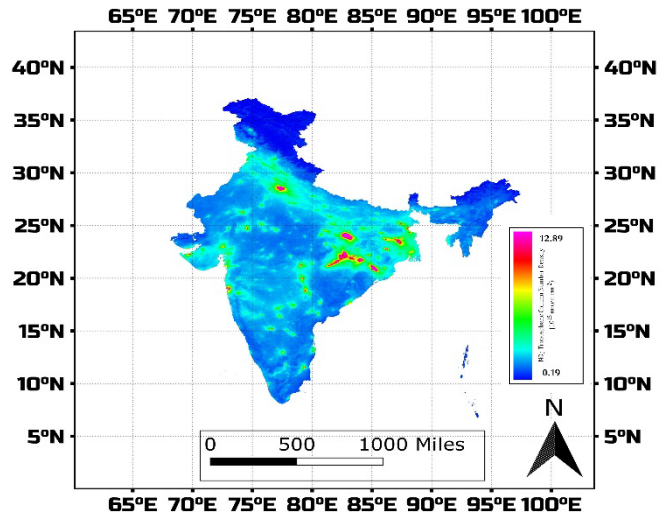
- What prompted fire studies during COVID vs. pre-pandemic?

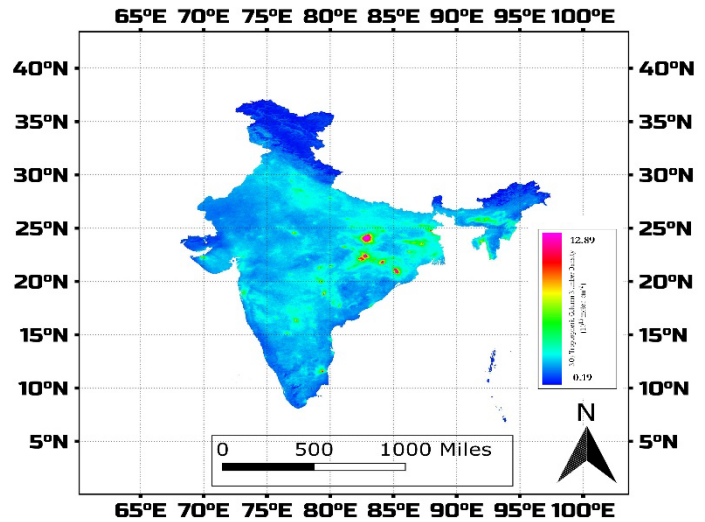
Spatial and temporal variations of Air pollution over 41 cities of India during the COVID-19 lockdown period

- How much was NO_2 pollution reduced during Phase-1 and 2 of the COVID-19 full country lockdown (March 25-May 3rd, 2020)?
- Specifically, how did NO_2 in the 2020-lockdown compare to the same period in 2019, when there was no lockdown?
- Which cities had the highest and least reduction in NO_2? Are there scaling effects in NO_2 levels in cities, i.e., based on the spatial distance to the city center?
- How do satellite derived NO_2 compare with ground-based measurements?
- What was the overall reduction in NO_2 for major cities across India and are the differences statistically significant?

TropOMI NO_2

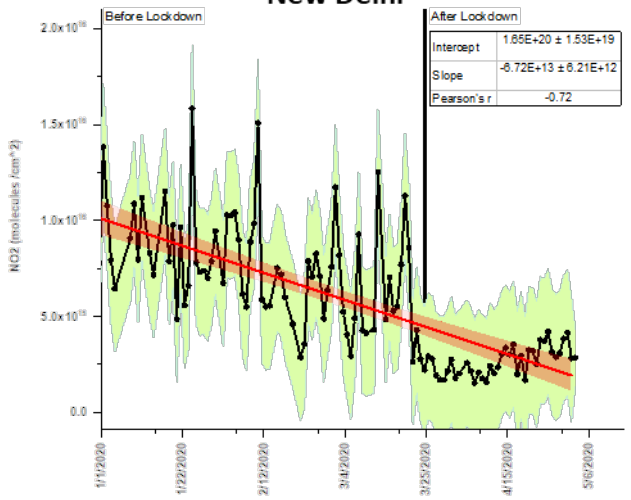


January 1st - March 25th, 2020

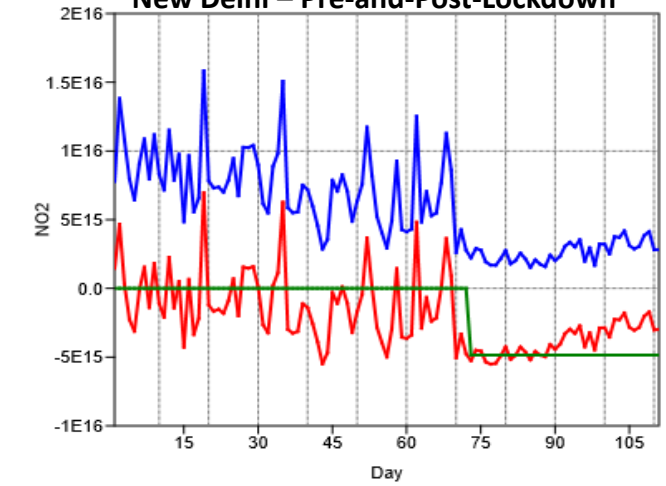


March 25th – May 3rd, 2020

New Delhi



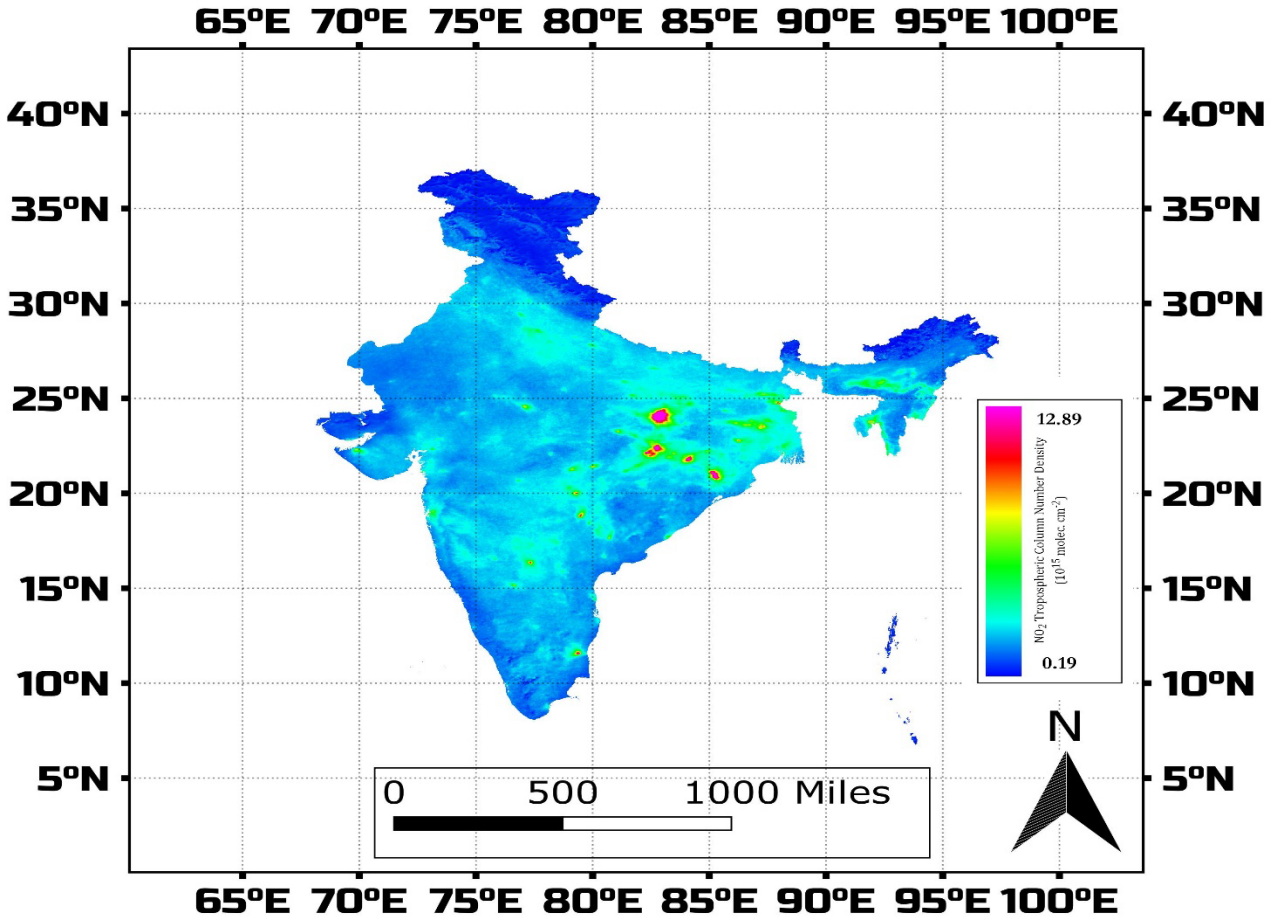
New Delhi – Pre-and-Post-Lockdown



Krishna Vadrevu et al., Nature Scientific Reports, 10, (1) (2020): 1-15

The Top Cities in India with NO_2 Reduction (2020)

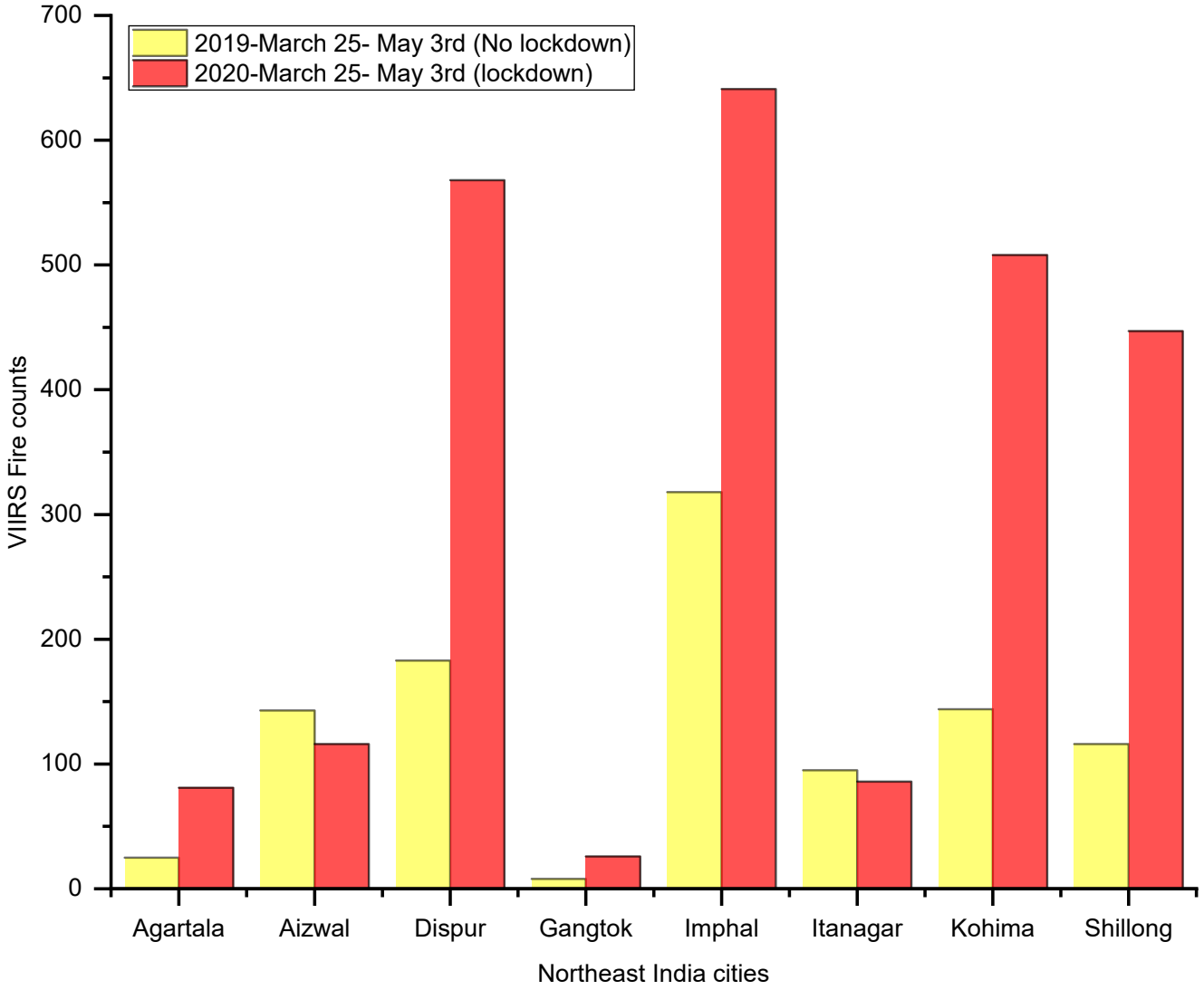
-New Delhi - 61.74%
-Delhi - 60.37%,
-Bangalore - 48.25%
-Ahmedabad - 46.20%
-Nagpur- 46.13%
-Gandhinagar- 45.64
-Mumbai -43.08%



March 25th – May 3rd, 2020

Krishna Vadrevu et al., Nature Scientific Reports, 10, (1) (2020): 1-15

NO_2 pollution in Northeast Indian cities DID NOT decrease during the COVID lockdown due to Vegetation Fires



Krishna Vadrevu et al., Nature Scientific Reports, 10, (1) (2020): 1-15

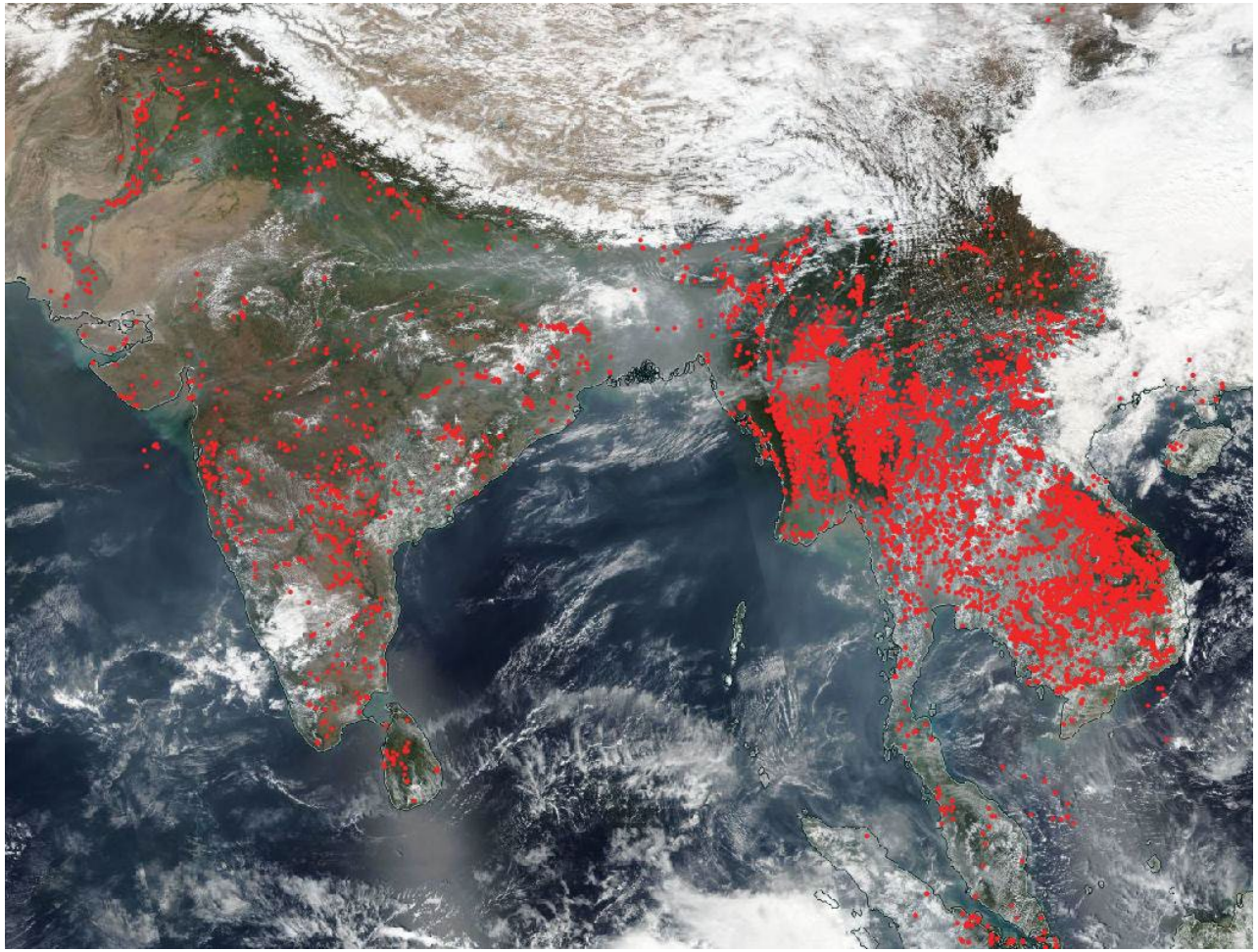


Figure 1. Suomi NPP/VIIRS fires and thermal anomalies shown as red dots (Day and Night) on March 02nd, 2022. The background image is NOAA-20/VIIRS corrected reflectance with true color (Red=Band I1; Green=Band M4 and Blue=Band M3). The VIIRS instrument is aboard the joint NASA/NOAA NOAA-20 (JPSS-1) satellite.

it is unclear whether vegetation fires and emissions were equally affected, which is the focus of this study

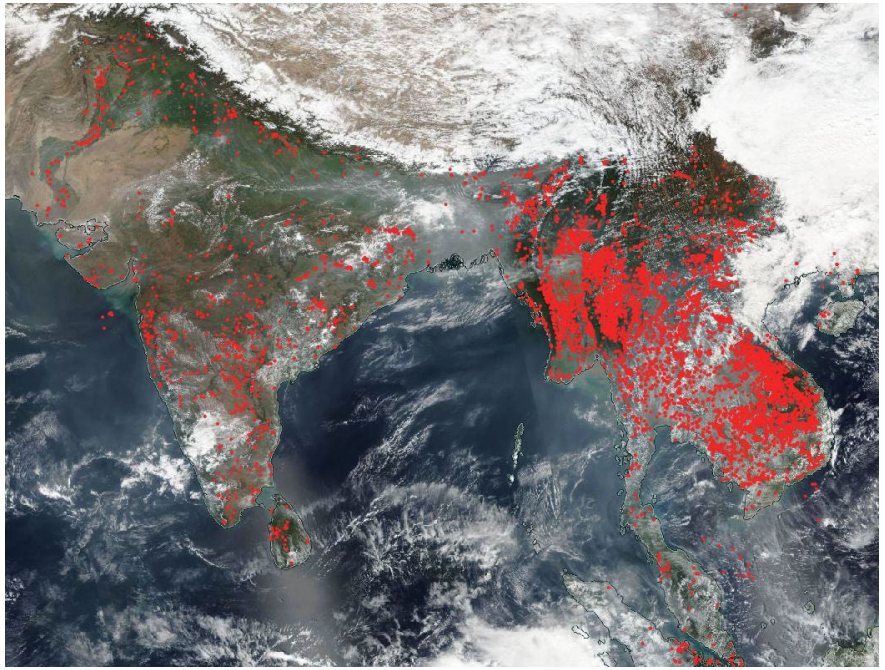
Questions Addressed

- How did the total number of fires vary during COVID-2020 year versus previous non-COVID year 2019 and pre-pandemic years (2012-2019) in SA/SEA countries?

- Which countries had the highest variations? Has the average fire intensity changed during 2020 compared to previous years?

- Which type of vegetation (forests, shrublands, croplands) was mostly burned during 2020?

- How did the total particulate matter (TPM) emissions vary during COVID-2020 year and previous years?



Suomi NPP/VIIRS fires and thermal anomalies shown as red dots (Day and Night) on March 02nd, 2022.

2020 - COVID Lockdowns in Different Countries

Country	Jan			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec		
	1	15	31	1	15	28	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31	1	15	31	1	15	30	1	15	31	1	15	30	1	15	31
Afghanistan																																				
Bangladesh																																				
Bhutan																																				
India																																				
Nepal																																				
Pakistan																																				
Sri Lanka																																				
Brunei												-																								
Cambodia												-																								
East Timor												-																								
Indonesia																																				
Laos																																				
Myanmar																																				
Philippines																																				
Singapore																																				
Thailand																																				
Vietnam																																				

Methodology

For the spatial analysis, we first gridded the daily VIIRS fire data at 0.5° for individual months and years (2012-2020). The monthly fire data (M) were given as,

$$M_{k,i} = \sum_{d=1}^{n} N_{k,d}$$

Where, *k* represents the 0.5°grid cells, *i* represent the month, $N_{k,d}$ represents fire counts data value for each day *d*, for each calendar month *i*.

The yearly FC data $Y_{k,l}$ for each grid cell *k* and year *l* is given as

$$Y_{k,l} = \sum_{i=1}^{12} M_{k,i}$$

For each 0.5°grid cell (*k*), we calculated the relative change (%) Y_c in fire counts during 2020-COVID year compared to 2019 non-COVID year as,

$$Y_c = \frac{Y_{k,2020} - Y_{k,2019}}{Y_{k,2019}} \times 100$$

We also compared the 2020-COVID year fire counts with the previous years (2012-2019) mean fire FC in two different steps:

i). The mean annual FC averaged between 2012 and 2019 denoted as *Avg* for each grid cell *k* and year *l* is calculated as,

$$Avg_{k,l} = \frac{\sum_{l=1}^{8} Y_{k,l}}{T_{k,l}}$$

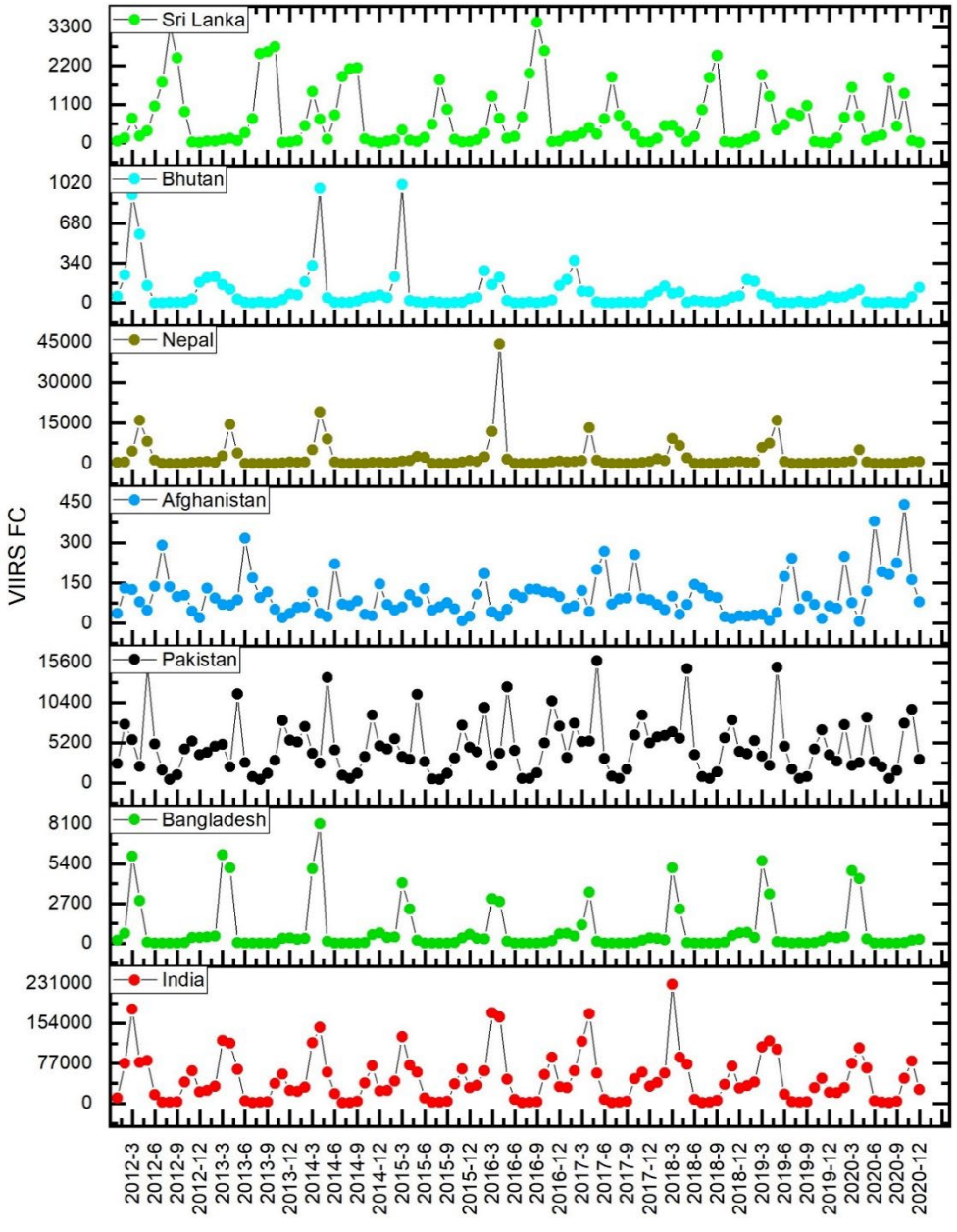
where T represents the total number of years spanning 2012 to 2019.

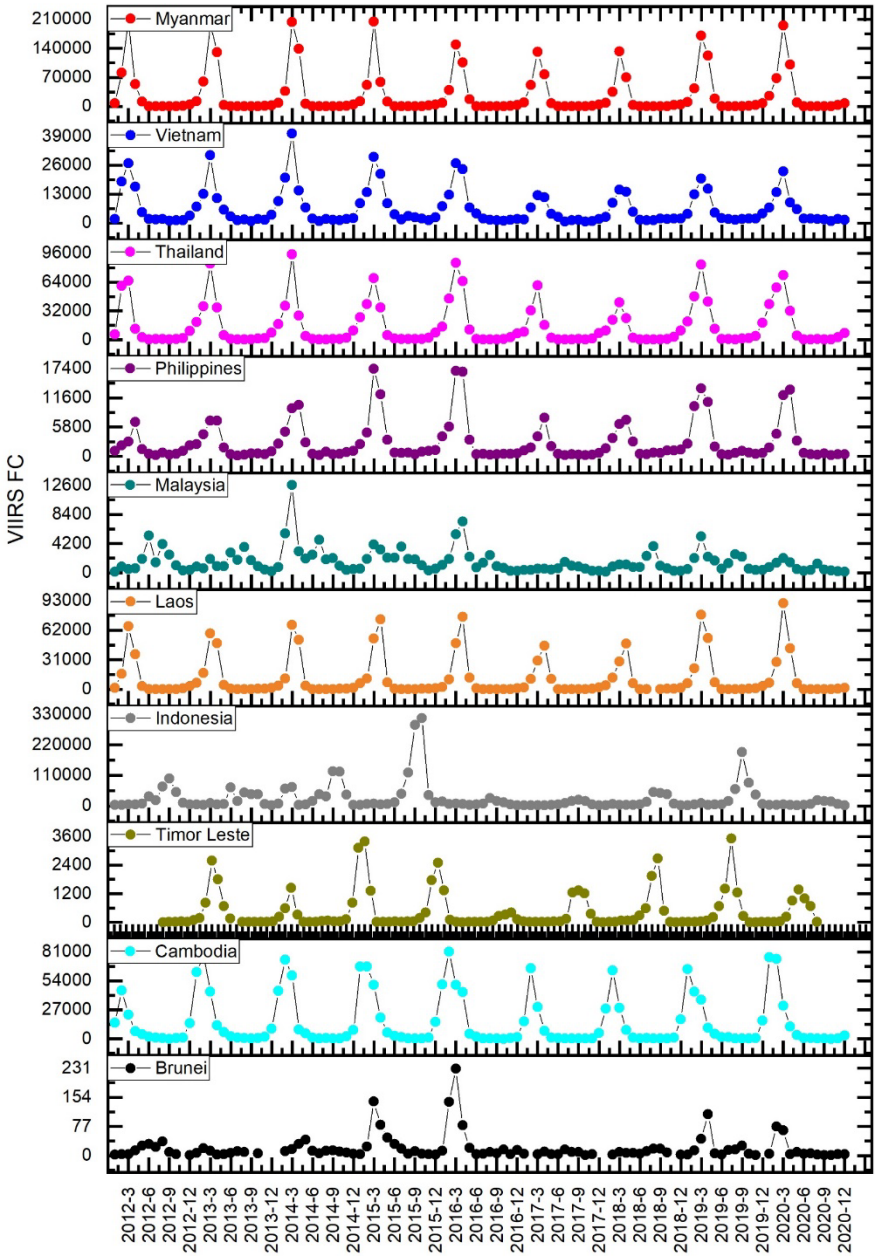
ii). The percent change P for each grid cell *k* and year *l* in FC between the year 2020 versus the *Avg* during previous years (2012-2019) is given as,

$$P_{k,l} = \frac{Y_{k,2020} - Avg_{k,l}}{Avg_{k,l}} \times 100$$

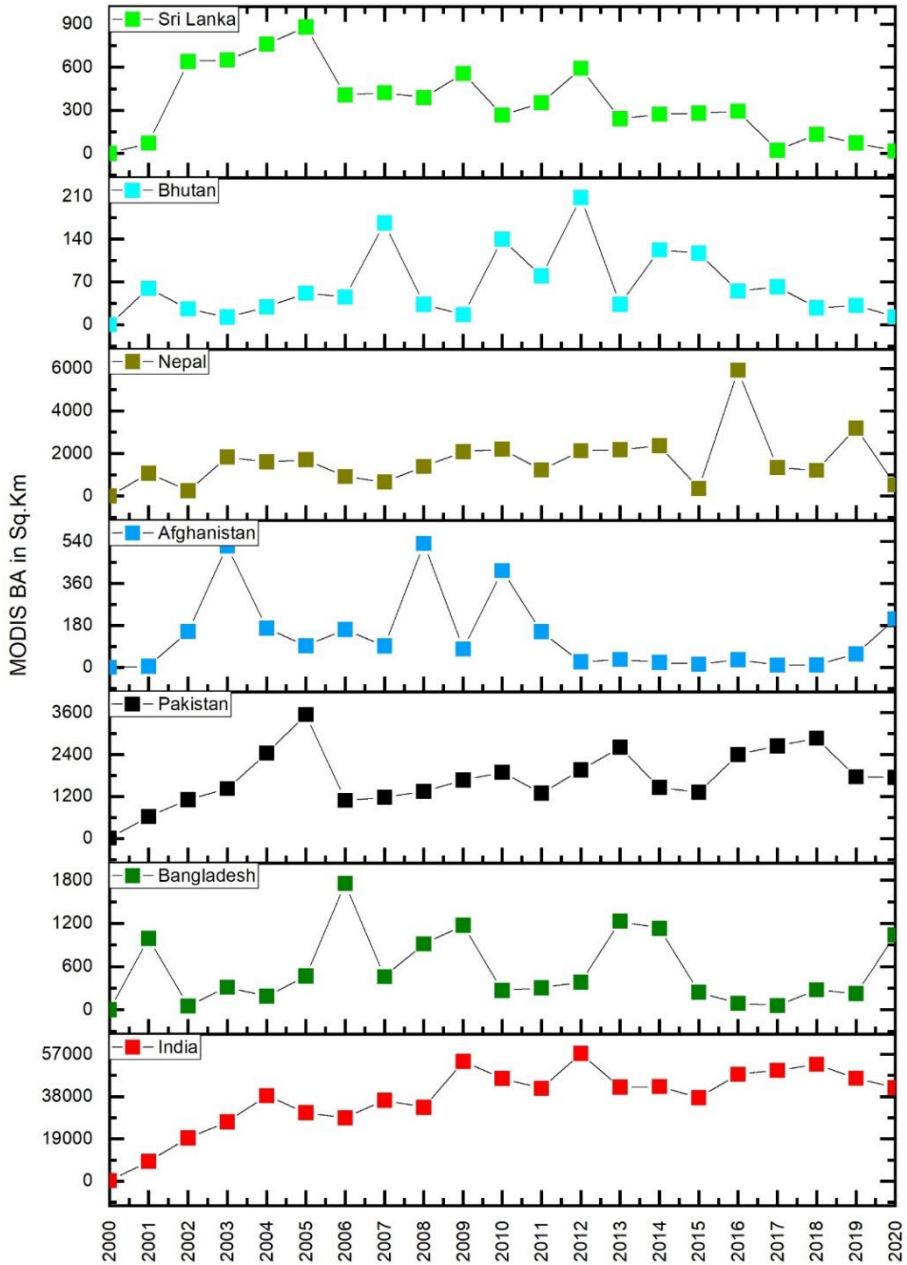
In the results section, we report the inter-annual variations in FC for both gridded and country-specific data.

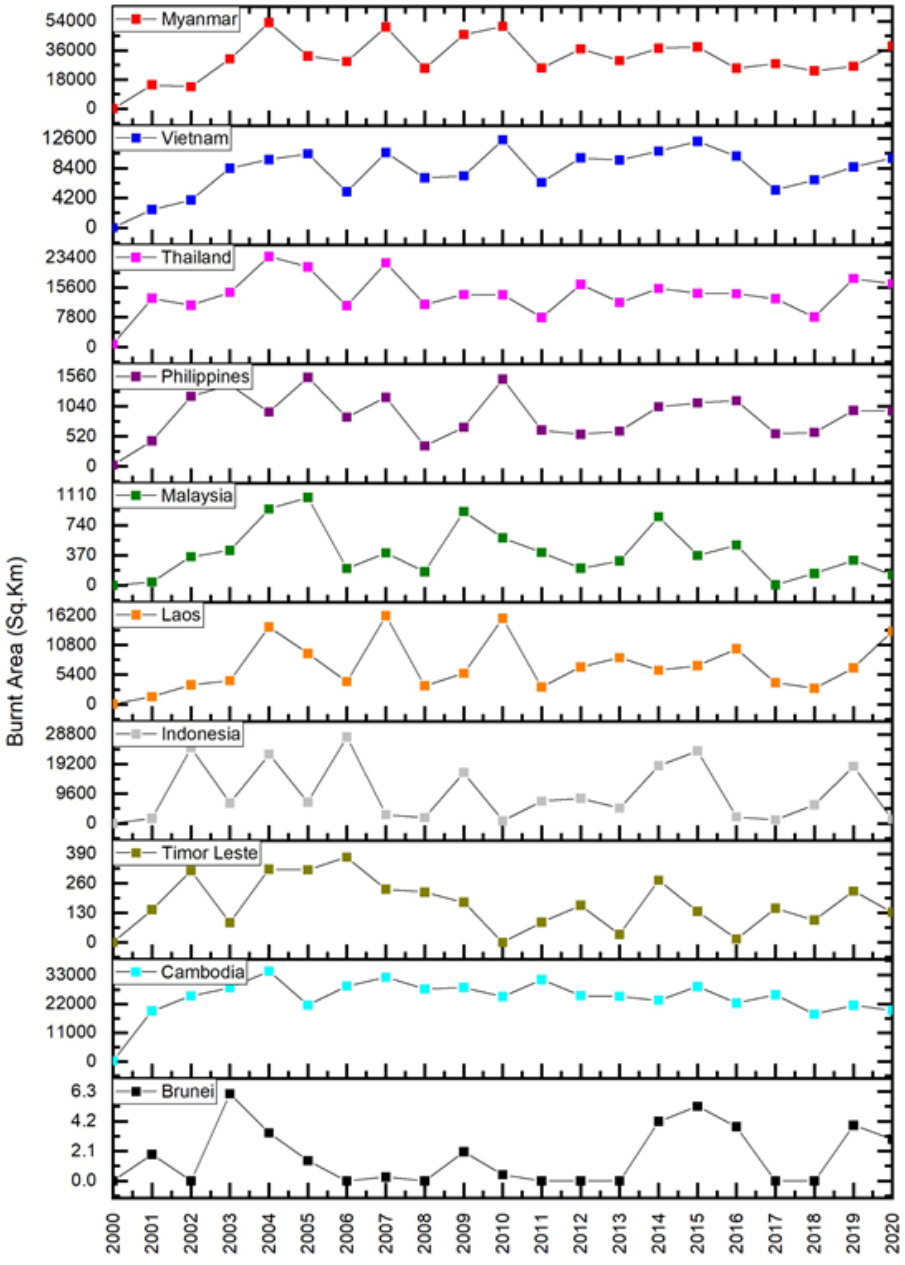
Active Fires and Trends in South and Southeast Asian Countries





Active Fires and Trends in South and Southeast Asian Countries





How did the total number of fires vary during COVID-2020 year versus previous non-COVID year 2019 and pre-pandemic years (2012-2019) in SA/SEA countries?

Percent increase/decrease in Fires in 2020 Pandemic versus 2019 non-Pandemic

Countries	2020 COVID year FC	2019 FC	Percent Increase/decrease in FC
Afghanistan	2164	856	152.80
Bangladesh	11054	10965	0.81
India	470667	531727	-11.48
Pakistan	50865	52647	-3.38
Nepal	8409	31299	-73.13
Bhutan	478	605	-20.99
Sri Lanka	7534	7185	4.85

Countries	2020 COVID year FC	2019 FC	Percent Increase/decrease in FC
Brunei	183	240	-23.75
Cambodia	200712	180640	11.11
Timor Leste	4217	7421	-43.17
Indonesia	87853	427265	-79.43
Laos	177161	172356	2.78
Malaysia	9333	19973	-53.27
Myanmar	409866	377443	8.59
Philippines	37398	33085	-11.53
Thailand	219482	234860	-6.54
Vietnam	70178	72266	-2.88

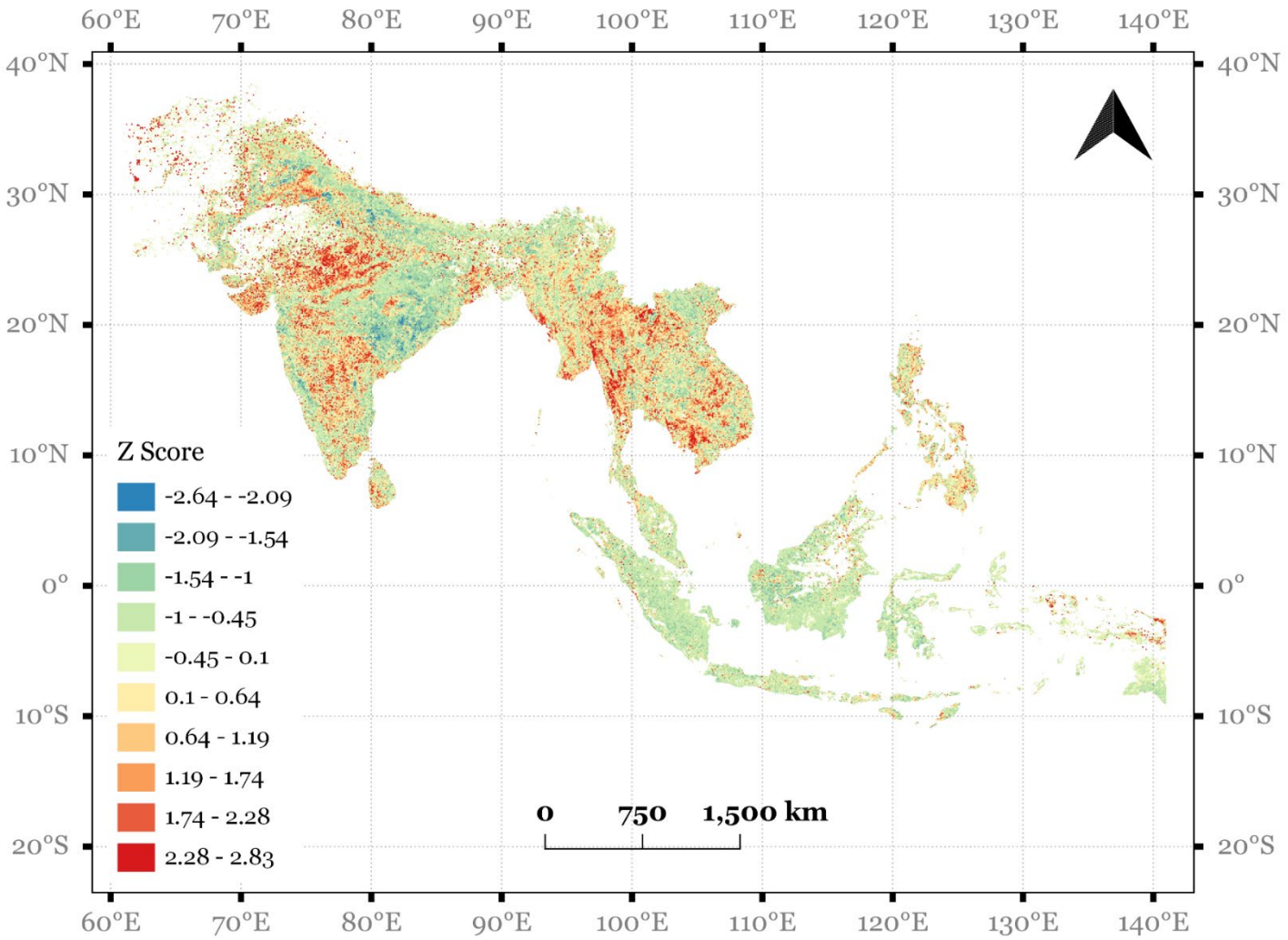
Percent increase/decrease in Fires 2020 Pandemic vs.pre-Pandemic (2012-2019)

Countries	2020 COVID year FC	Mean Pre-COVID years FC(2012-2019)	Percent Increase/decrease in FC
Afghanistan	2164	1071	102.05
Bangladesh	11054	10229.625	8.05
India	470667	566274	-16.88
Pakistan	50865	56270.625	-9.60
Nepal	8409	28888.625	-70.89
Bhutan	478	1137.125	-57.96
Sri Lanka	7534	8202.25	-8.14

Countries	2020 COVID year FC	Mean Pre-COVID years FC(2012-2019)	Percent Increase/decrease in FC
Brunei	183	212	-13.88
Cambodia	200712	187333	7.14
Timor Leste	4217	5833	-27.70
Indonesia	87853	345365	-74.56
Laos	177161	135996	30.26
Malaysia	9333	20377	-54.19
Myanmar	409866	345234	18.72
Philippines	32807	33085	0.84
Thailand	219482	181174	21.14
Vietnam	70178	78736	-10.86

- *What about spatial variations? Was fire density different in 2020 compared to previous years (2012-2020)?*

Z-score map of fires depicting deviation in fires 2020 pandemic year compared to previous years (2012-2020)

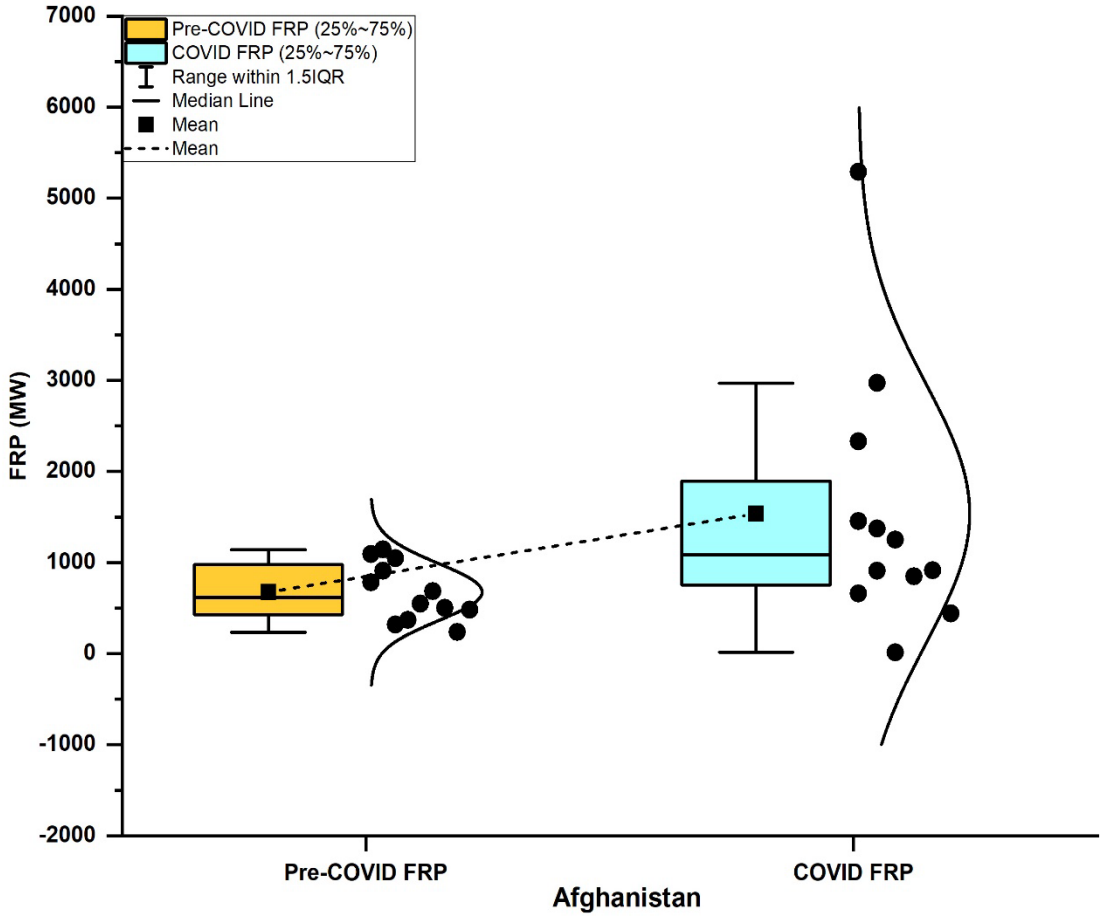


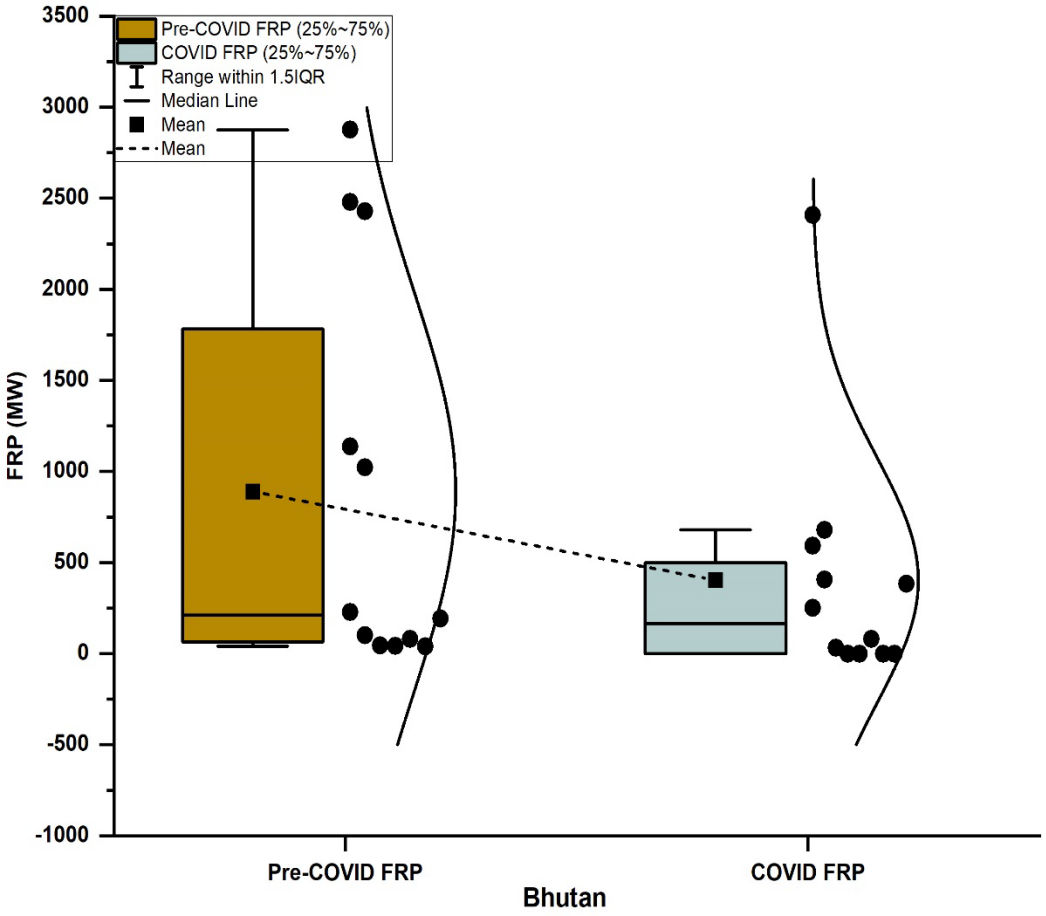
The negative scores indicate places where there was reduced FC and positive values indicate increased FC.

- *Did fire intensities also change (2012-2020)?*

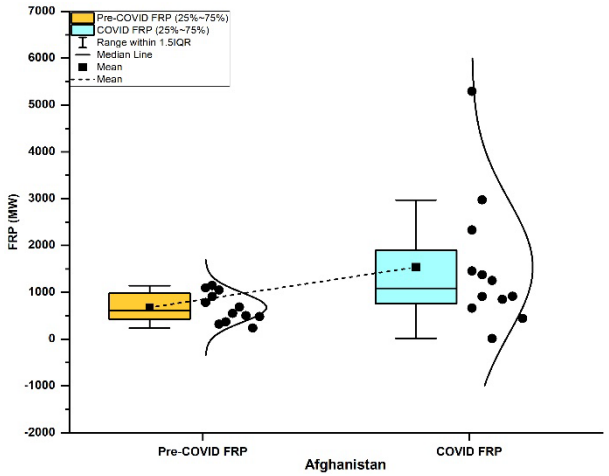
South Asia

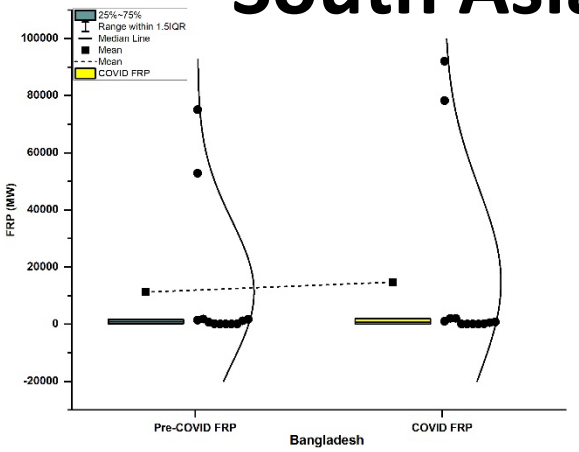
Statistical differences in FRP 2020 pandemic year vs. previous years (2012-2019)

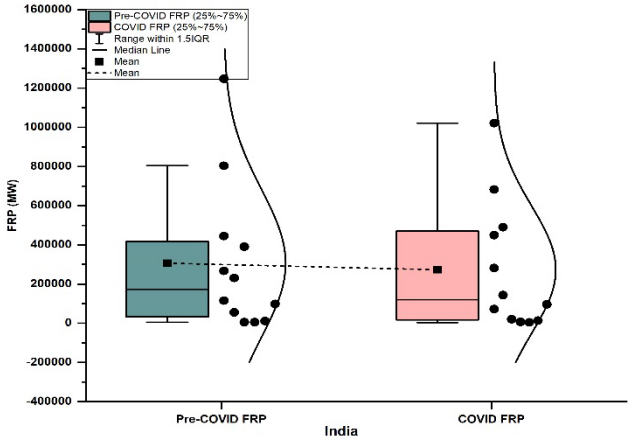


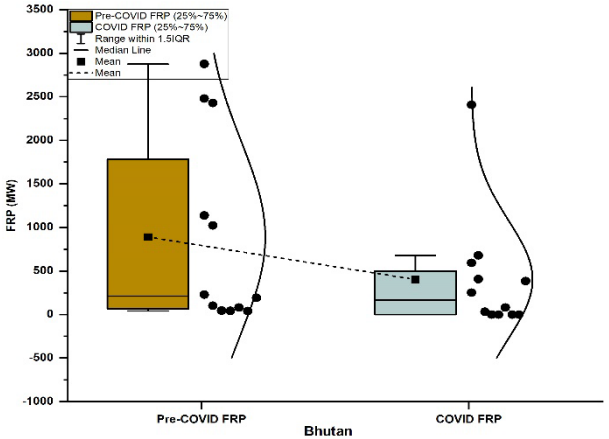


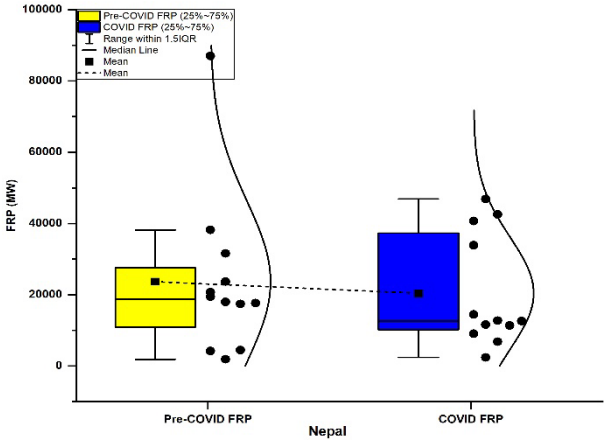
South Asia

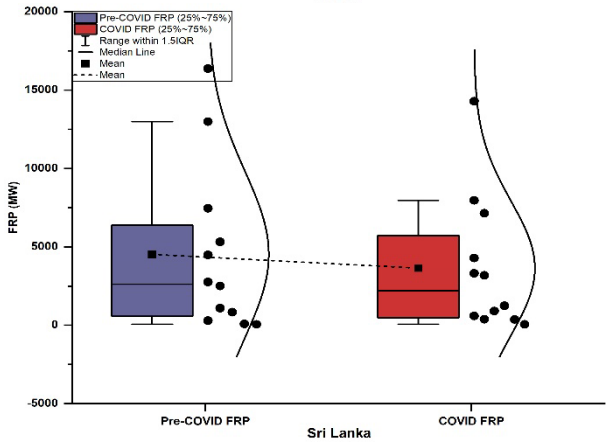


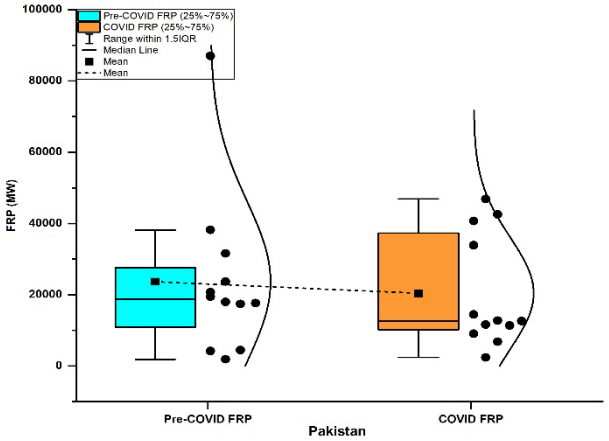












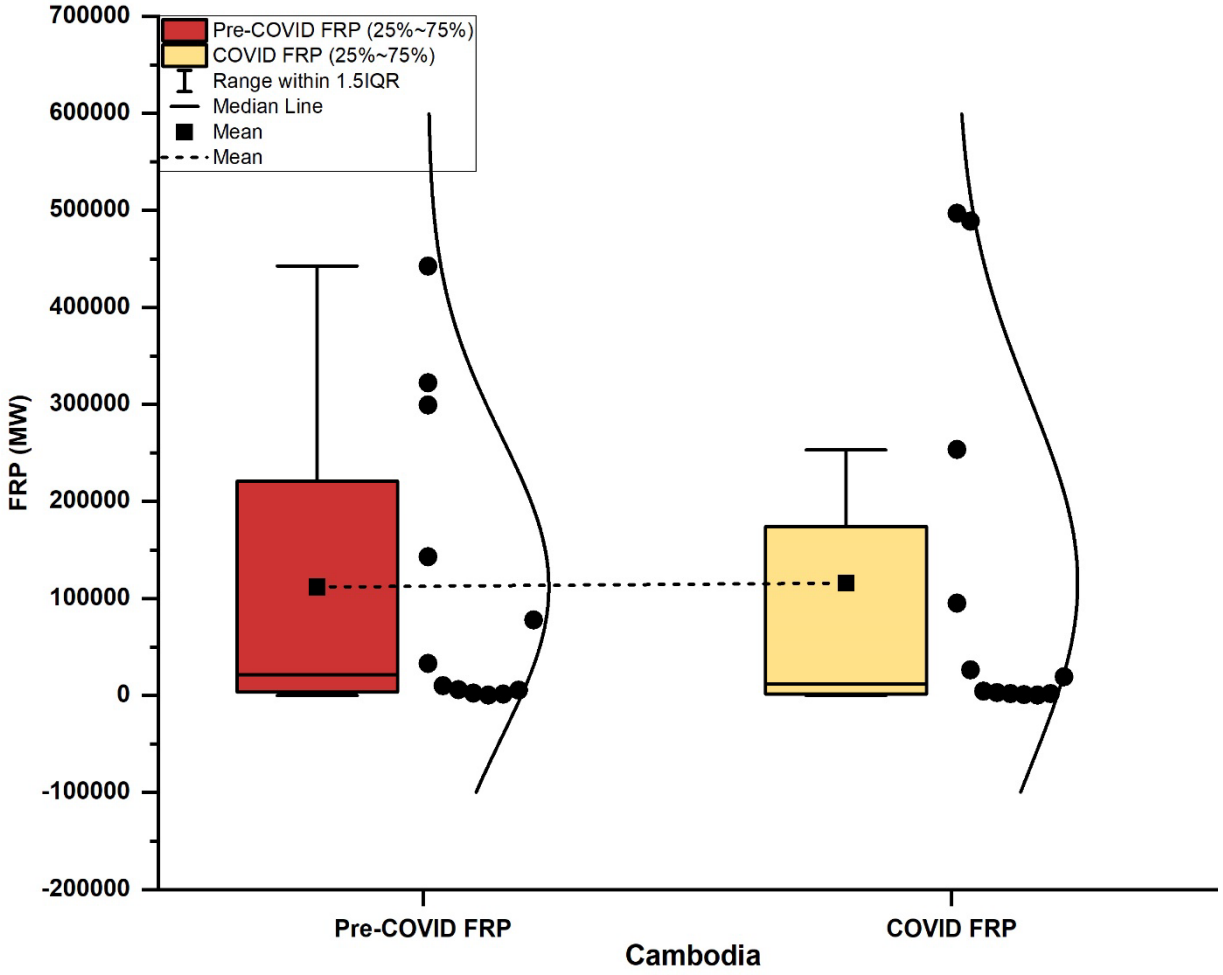
Statistical differences in FRP 2020 pandemic year vs. previous years (2012-2019)

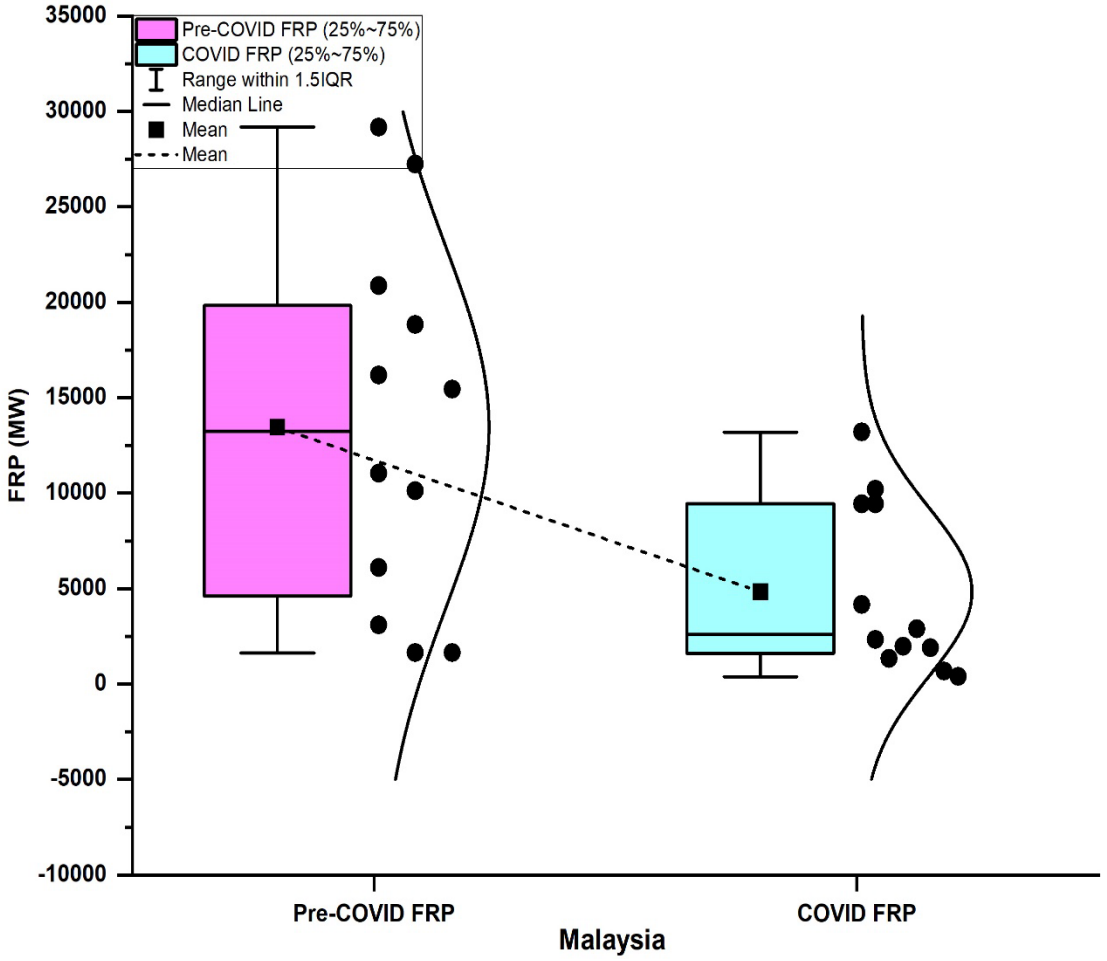
Increase is noted for Afghanistan and Bangladesh

A clear decrease is noted for Bhutan, Nepal, Sri Lanka and Pakistan

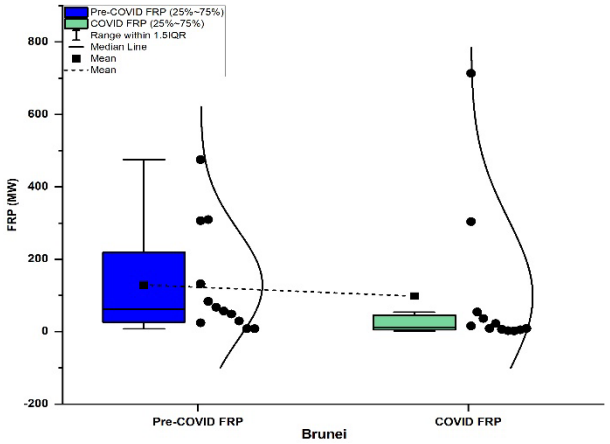
Southeast Asia

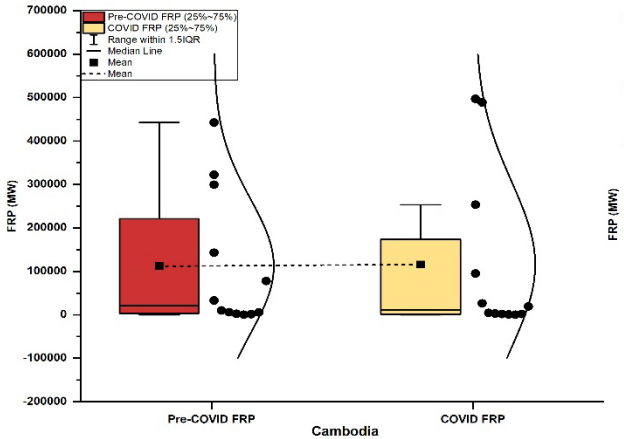
Statistical differences in fires 2020 pandemic year vs. previous years (2012-2019)

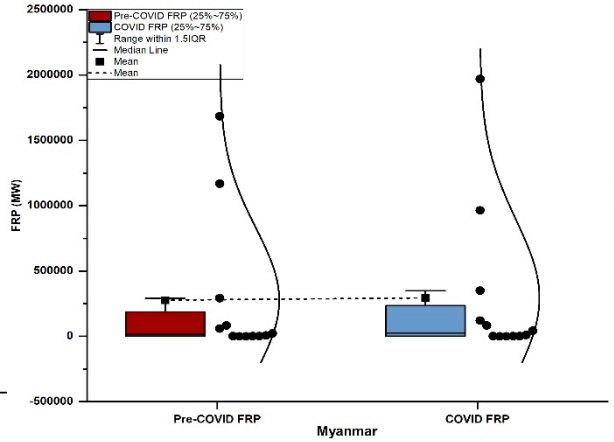


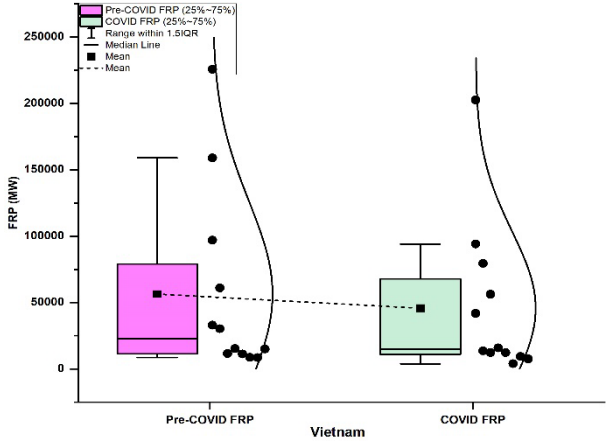


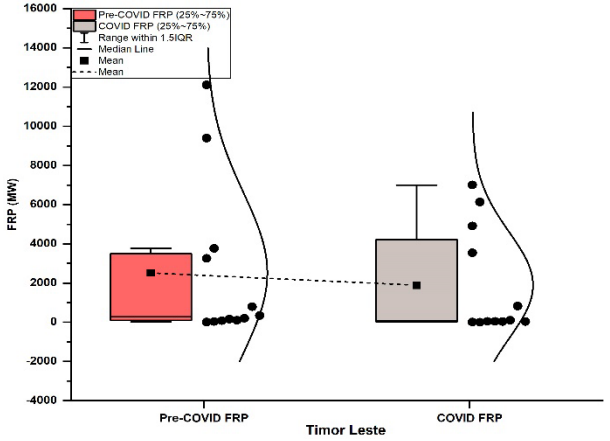
Southeast Asia

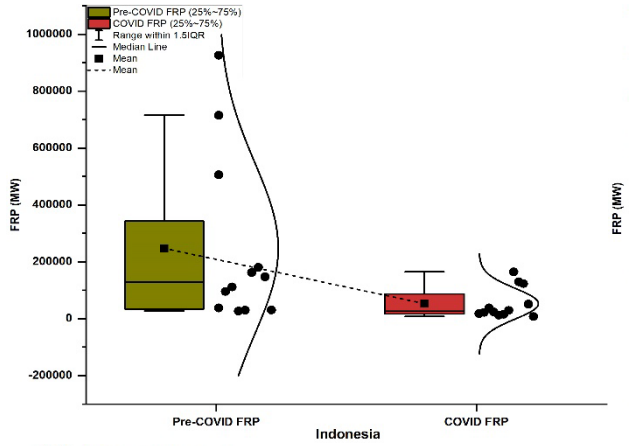


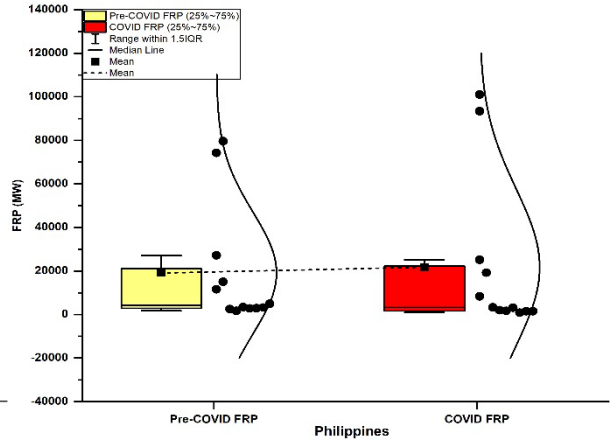


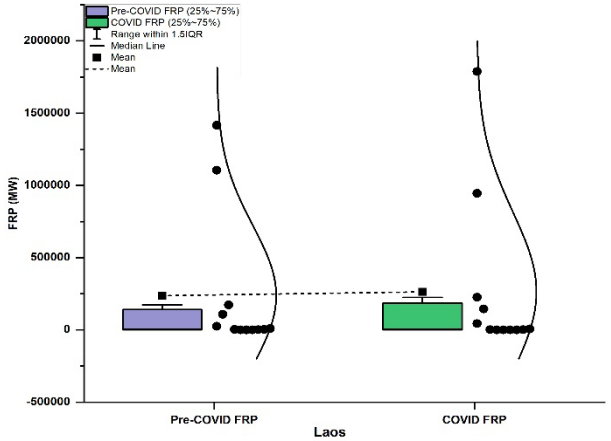


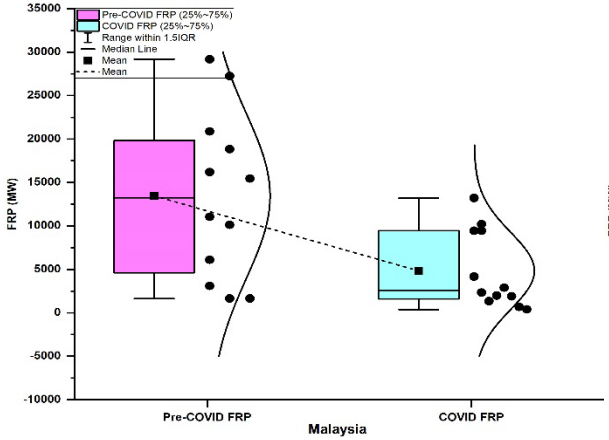


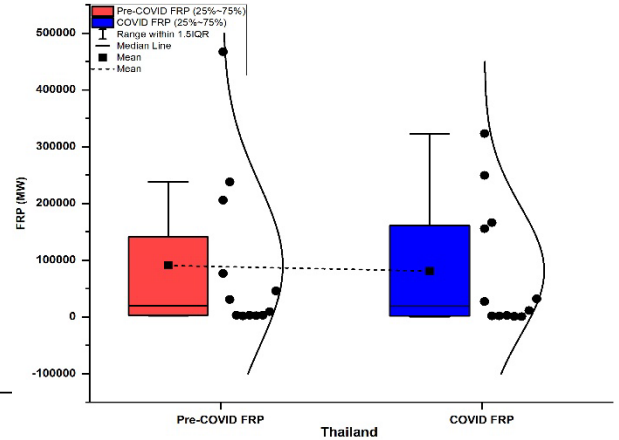












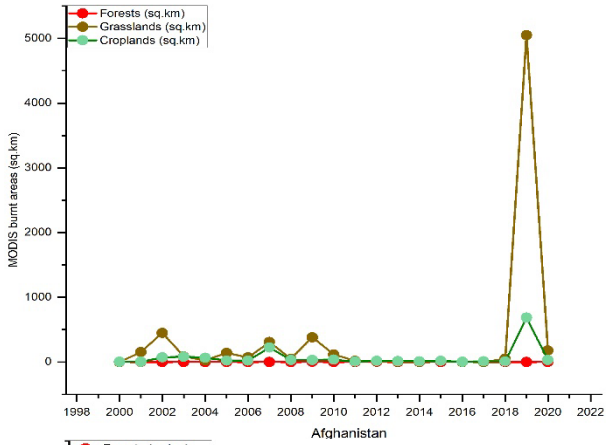
Statistical differences in FRP 2020 pandemic year vs. previous years (2012-2019)

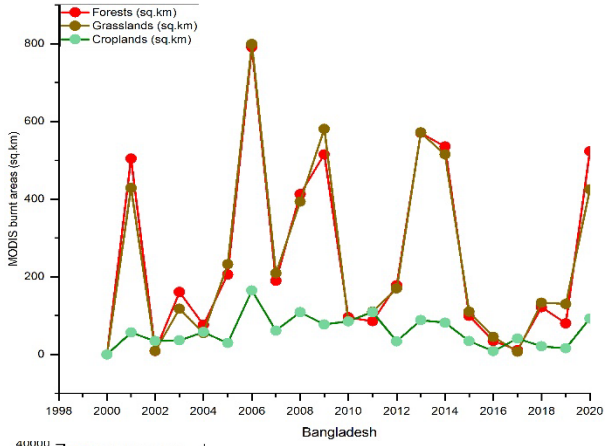
Slight increase is noted for Philippines and Laos.

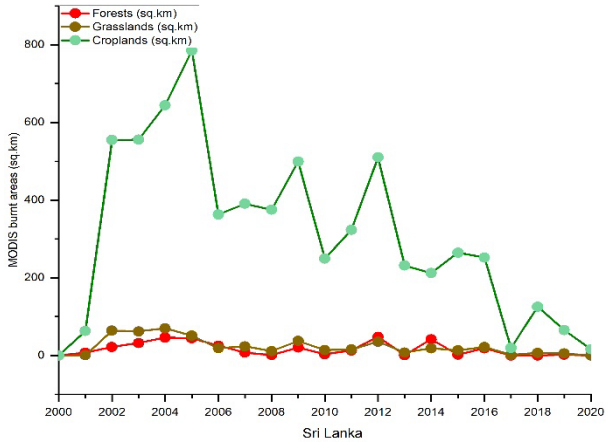
A clear decrease is noted for Vietnam, Indonesia, Malaysia.

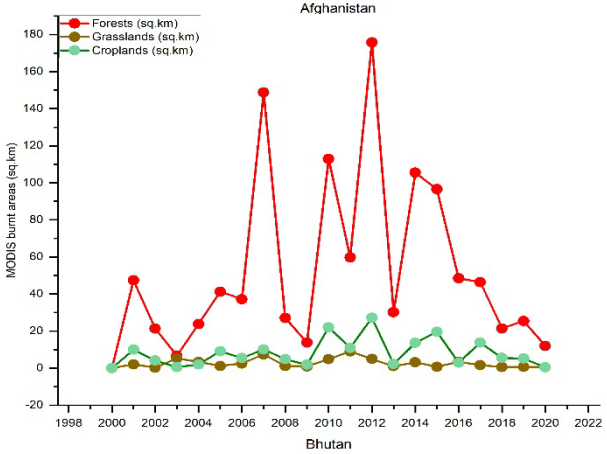
Which type of vegetation (forests, shrublands, croplands) was mostly burned during recent years?

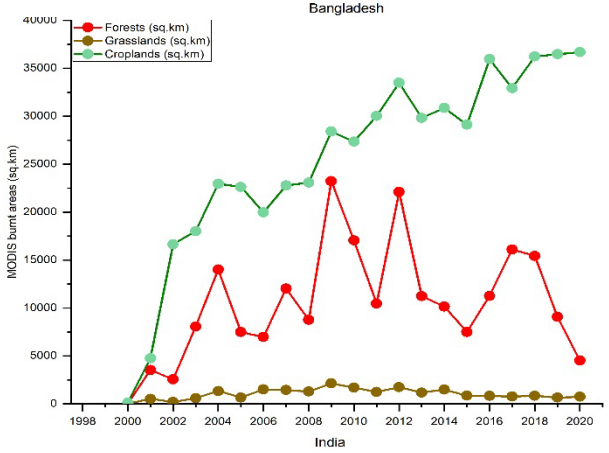
Burnt Areas, South Asian Countries

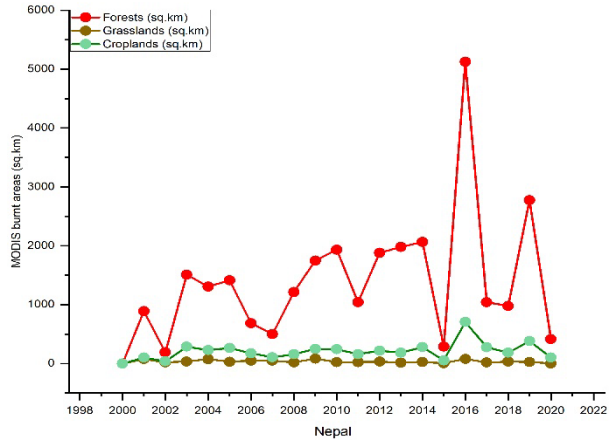


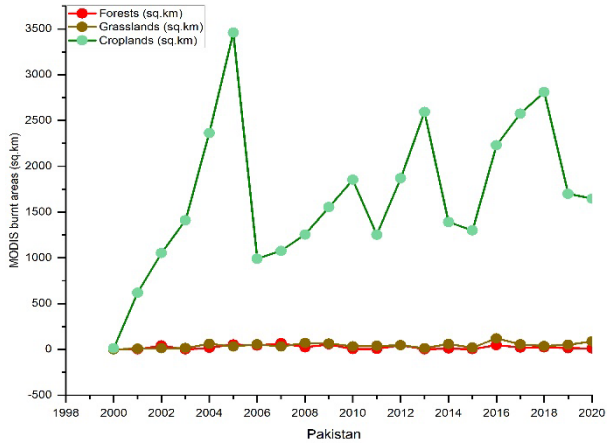










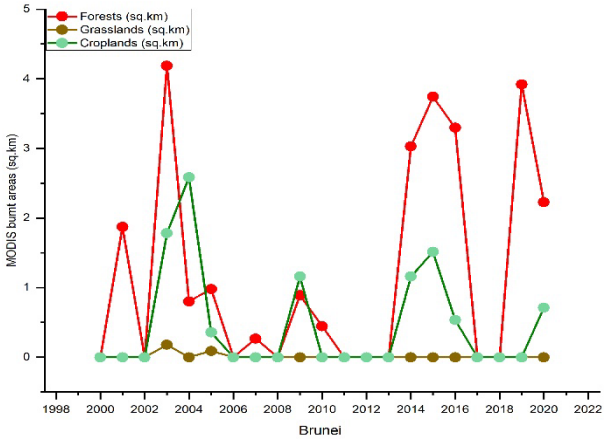


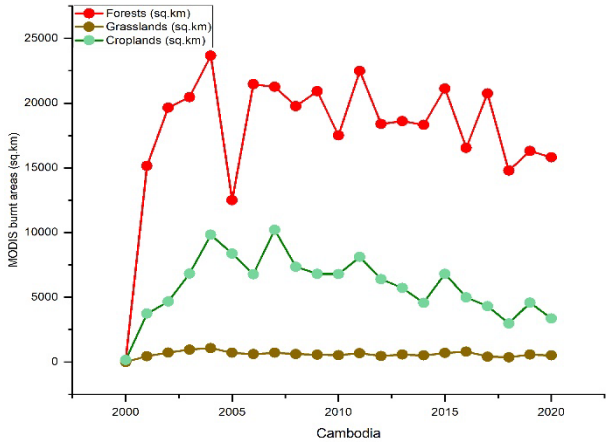
Ag.dominant fires: Sri Lanka, India, Pakistan

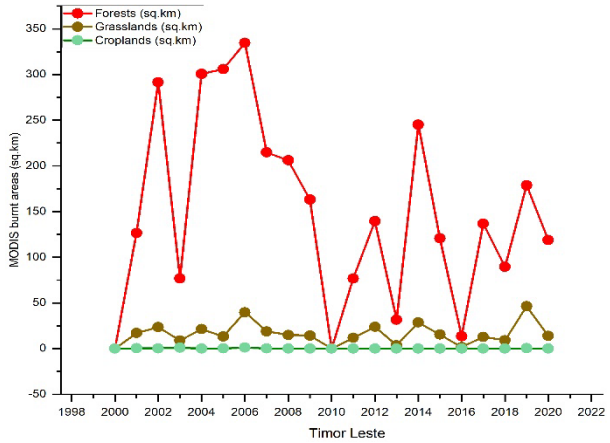
Forest fires: Bhutan and Nepal

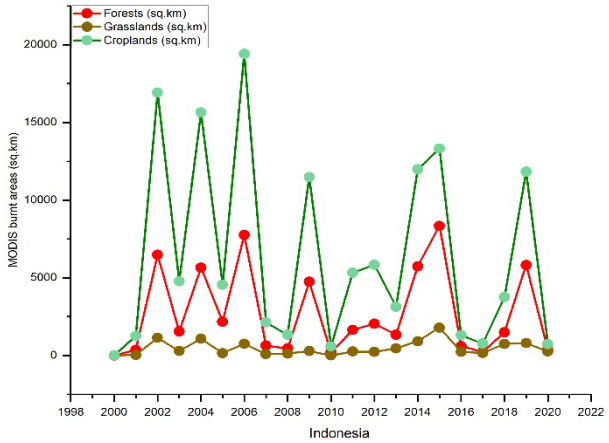
Mixed: Bangladesh

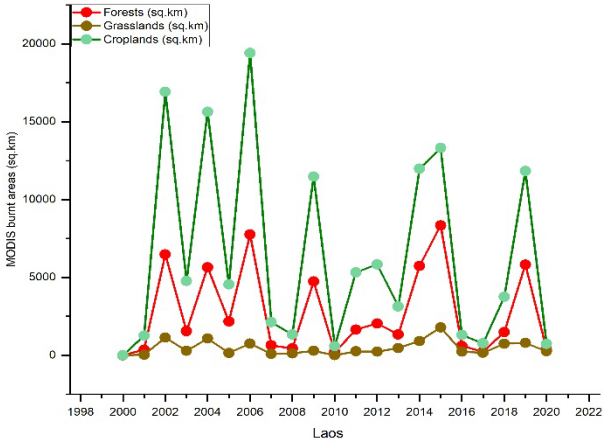
Burnt Areas, Southeast Asian Countries

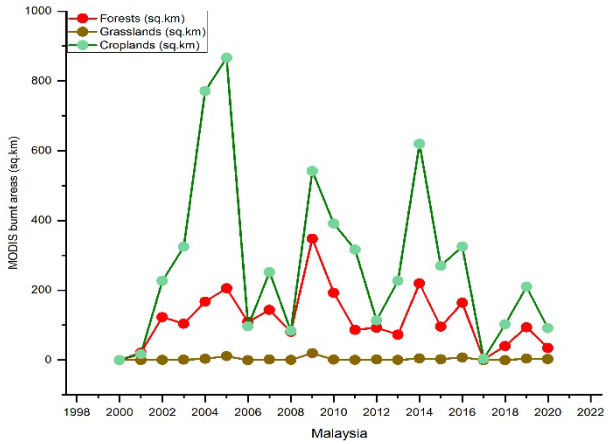


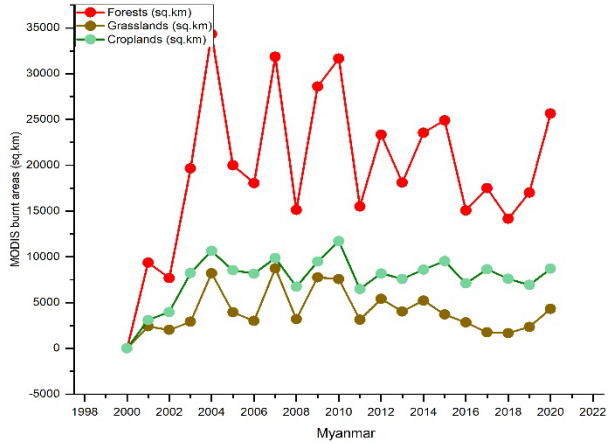


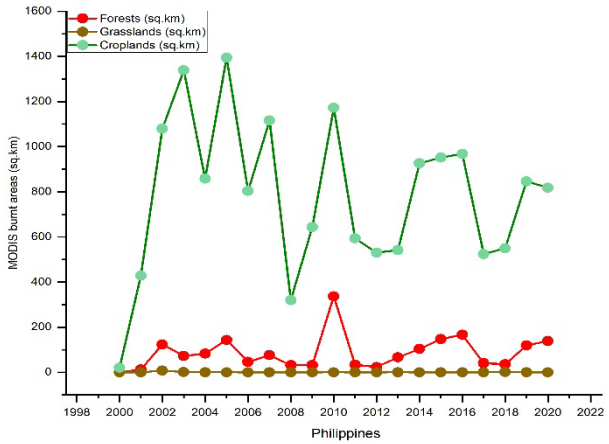


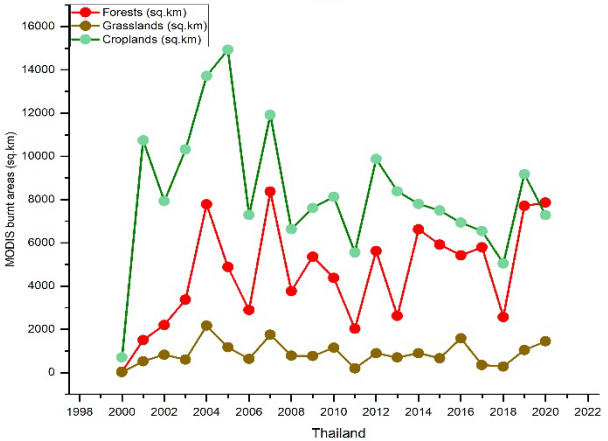


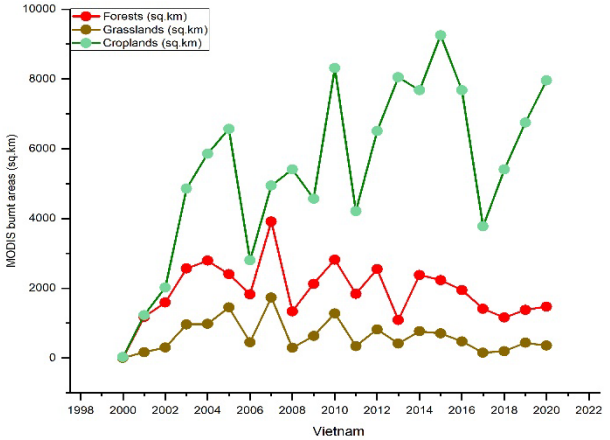










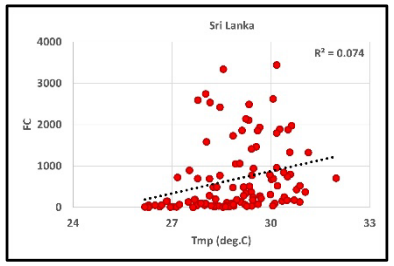


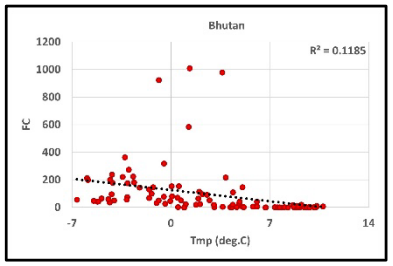
Ag.dominant fires: Indonesia, Laos, Malaysia, Philippines, Thailand and Vietnam

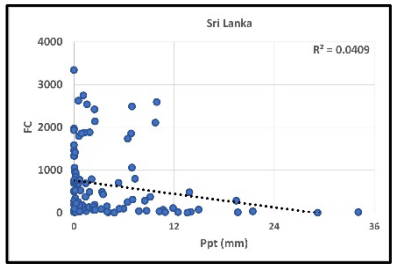
Forest fires: Cambodia, Timor Leste, Myanmar

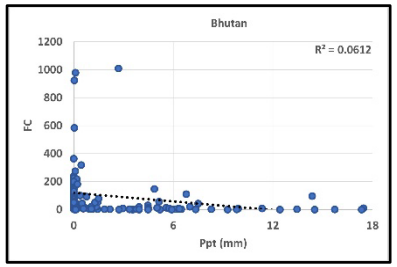
- *What is the role of Climate parameters in governing fires (2012-2020)?*

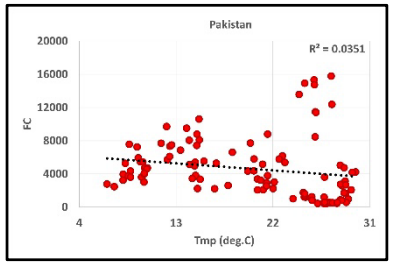
South Asia – Fires versus Temperature and Precipitation Correlations

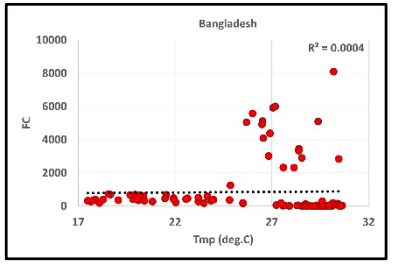


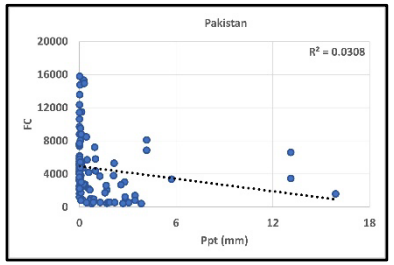


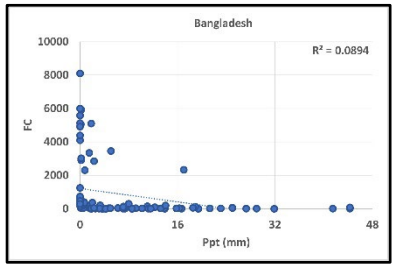


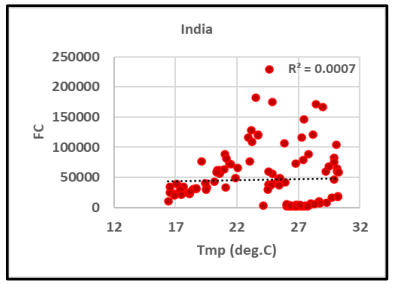


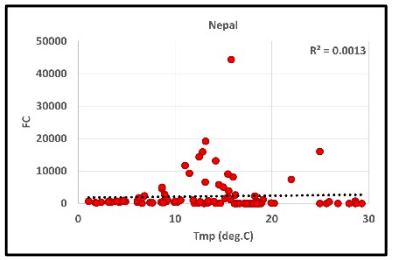


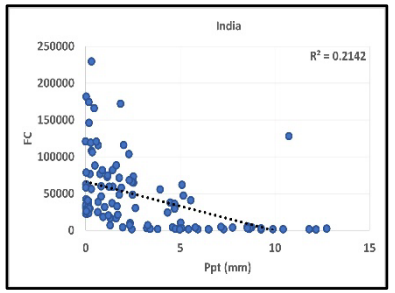


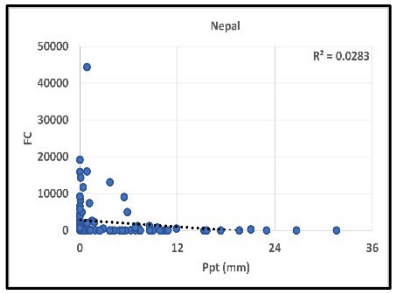


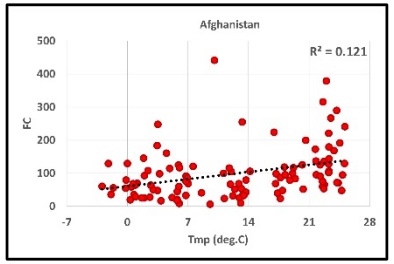


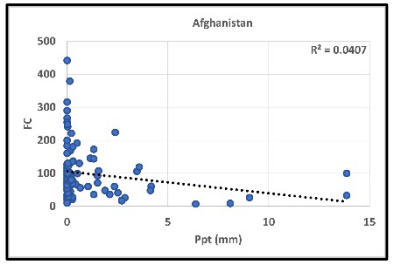






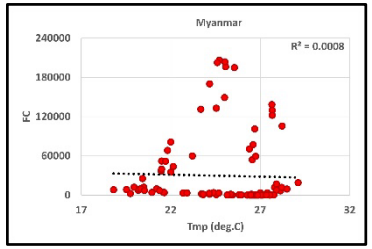


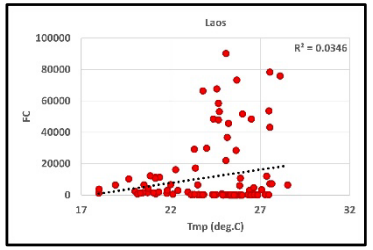


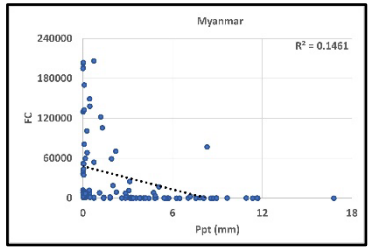


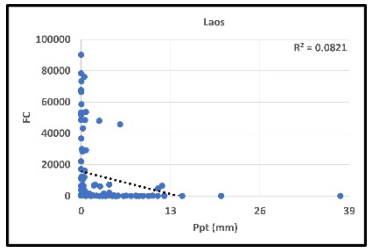
Temperature and Precipitation Correlations in relation to Fires (2012-2020) were poor in South Asian countries.

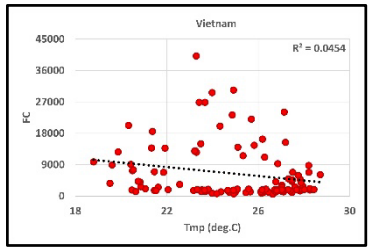
Southeast Asia – Fires versus Temperature and Precipitation Correlations

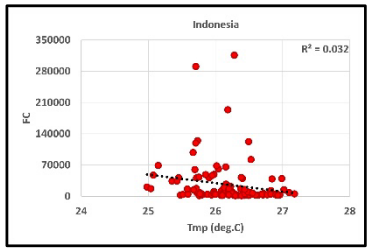


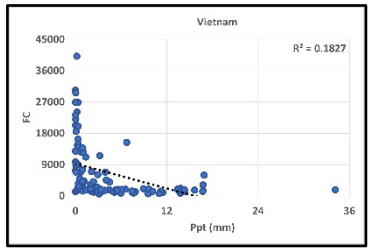


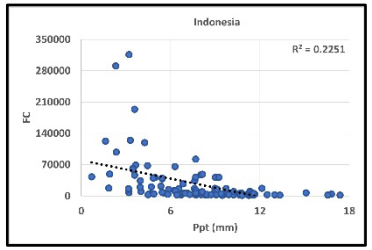


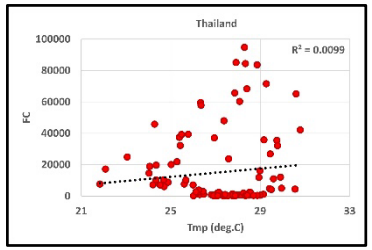


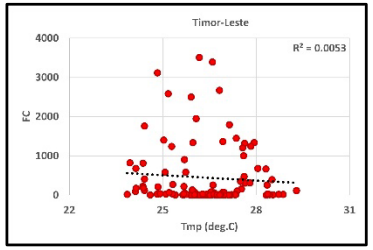


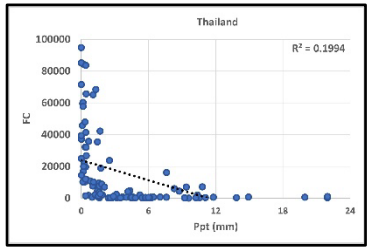


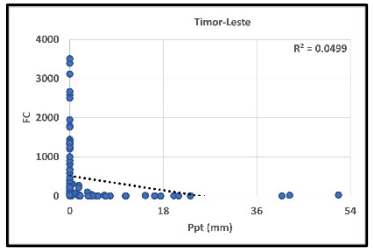


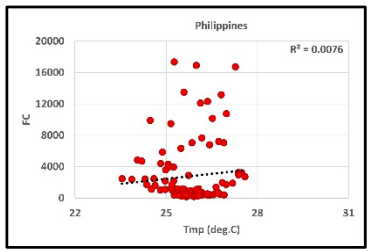


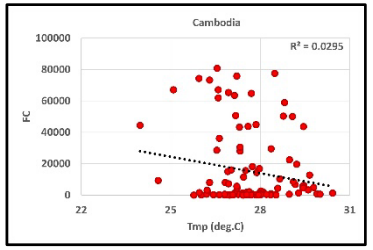


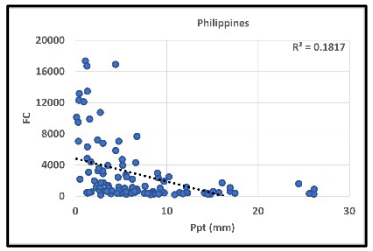


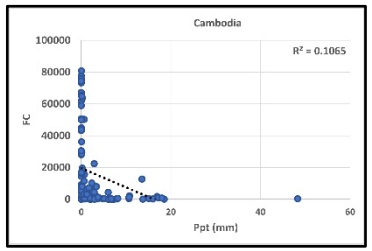


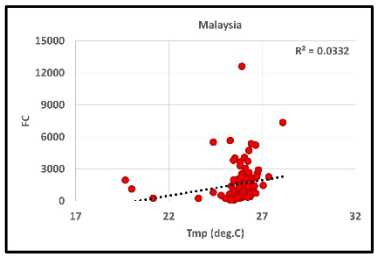


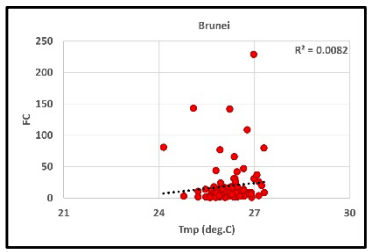


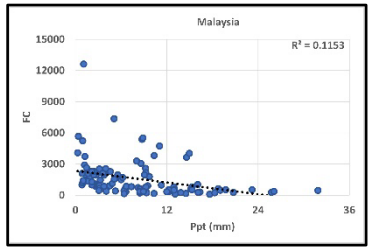


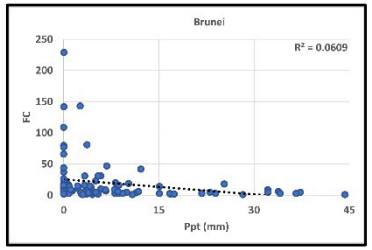












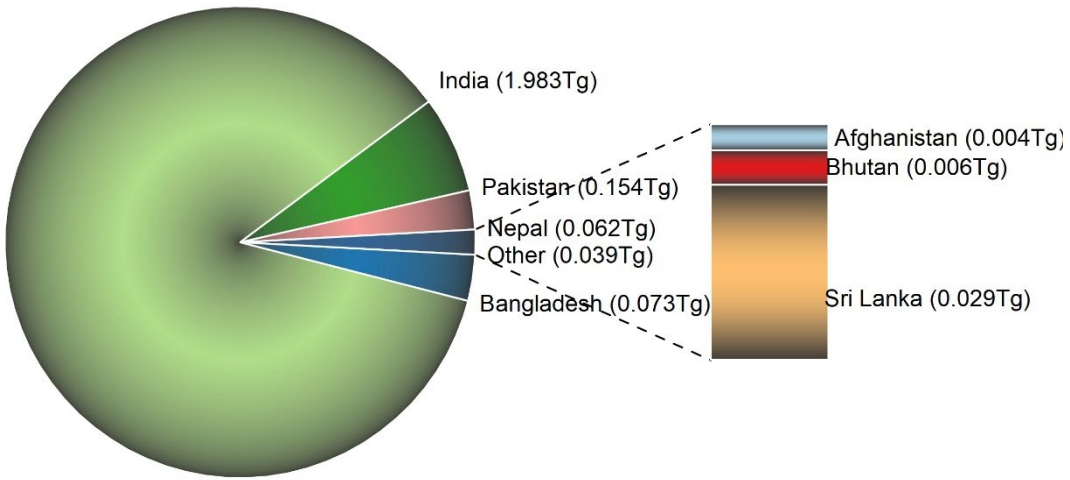
Temperature and Precipitation Correlations in relation to Fires (2012-2020) were poor.

However, relatively, fires showed higher coefficient of determination with precipitation than temperature.

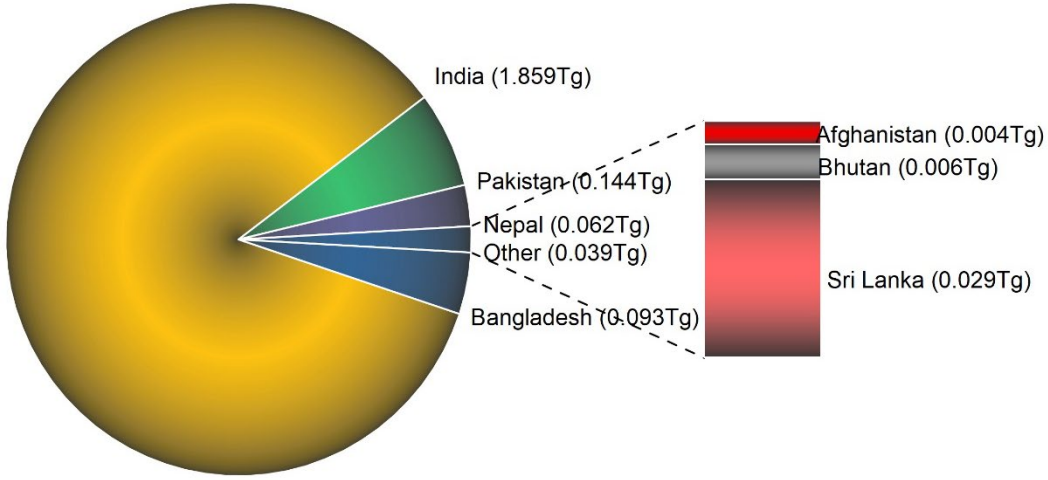
- *What about the fire related emissions? How did fire related emissions compare with previous years (2012-2019)?*

Fire Related Total Particulate Matter (TPM) Emissions (Tg) from South Asian Countries

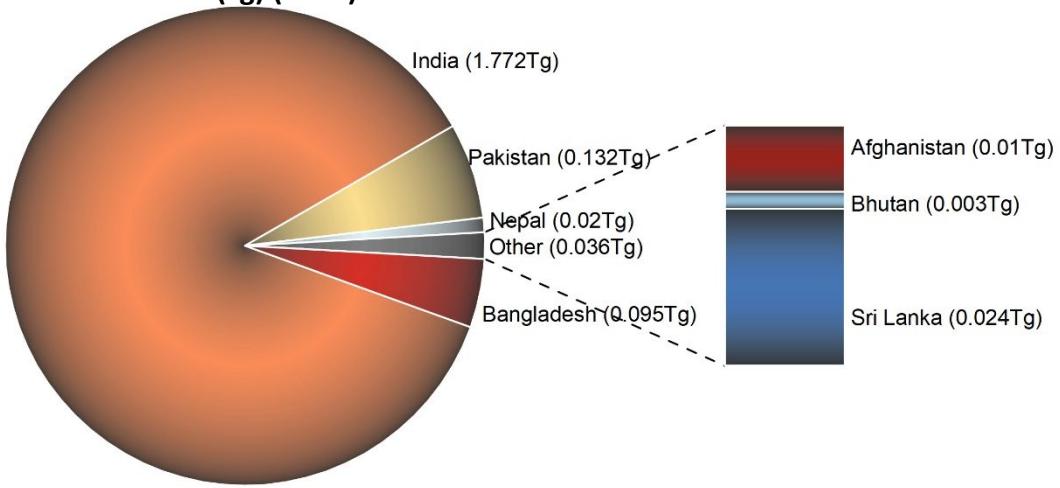
a.Mean TPM 2012-2019



b.TPM (Tg) (2019)



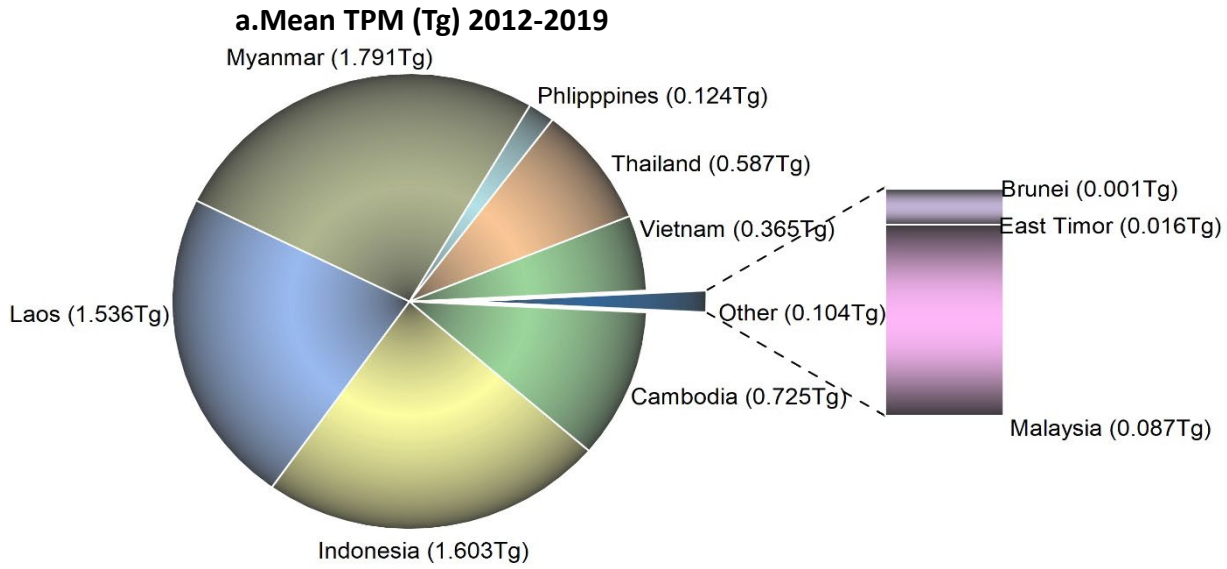
c. TPM (Tg) (2020)

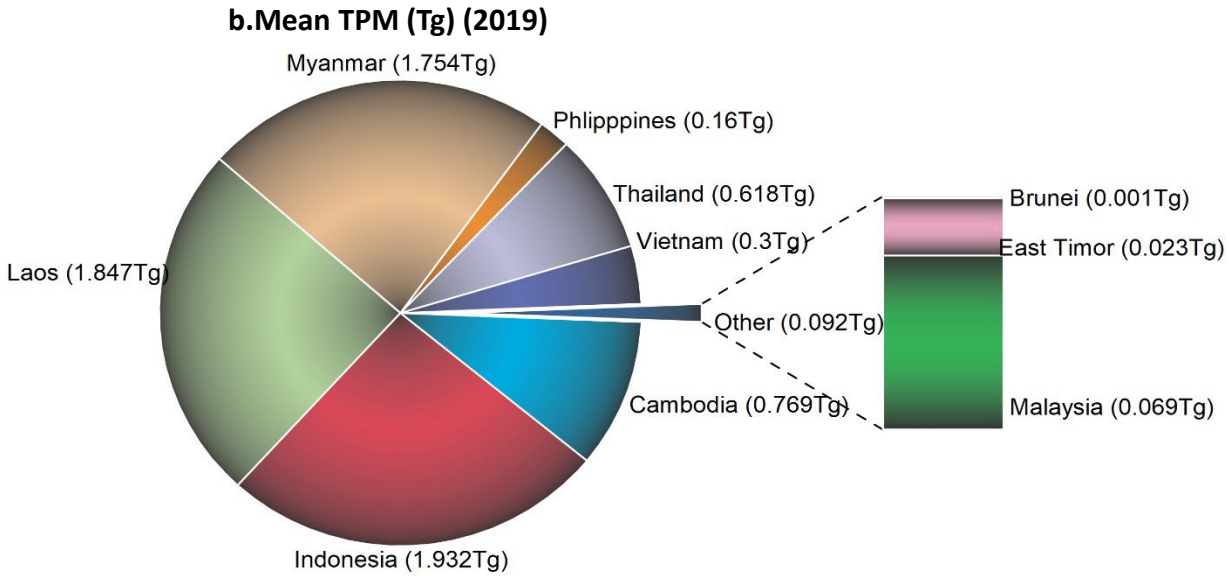


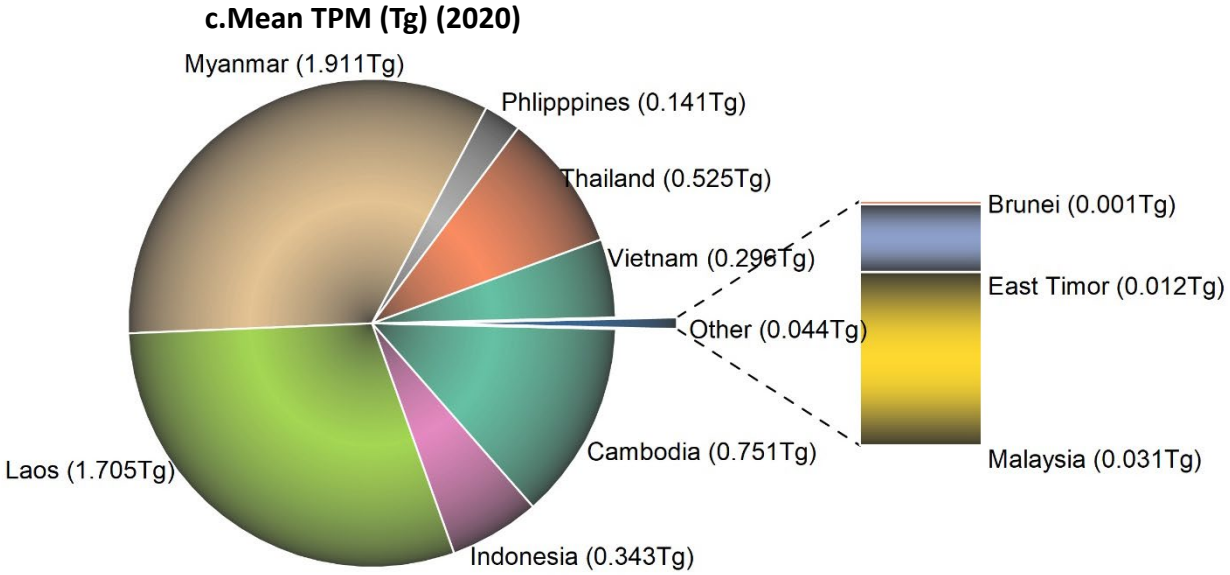
A reduction in TPM emissions has been observed during COVID-2020 for most of the countries, except Afghanistan and Bangladesh.

2020-COVID year had an overall reduction of ~0.26Tg TPM emissions compared to previous non-COVID years and 0.14Tg less than 2019 non-COVID year.

Fire Related Total Particulate Matter (TPM) Emissions (Tg) from Southeast Asian countries







A reduction in TPM emissions has been observed during COVID-2020 for most of the countries, except Myanmar, Laos, Cambodia and Philippines.

2020-COVID year had an overall reduction of ~1.11Tg TPM emissions compared to previous non-COVID years and 1.75Tg less than 2019 non-COVID year.

Addressing Drivers or Causative Factors at Varied Spatial scales is Challenging

- Addressing inter-annual variations in fires, including the recent decline in 2020, requires additional data such as demographics, migration, and land use policies useful for fire management and mitigation in the region.

-Most of the fires observed in both SA/SEA are related to the agriculture sector, mainly due to clearing agricultural residues after harvest.

-Due to the COVID lockdown, the labor shortage might have reduced post-harvest residue management practices, including crop residue fires.

-Also, forest-related tourism and visitor attractions to natural areas might have slowed down due to COVID-19 travel restrictions - reduced accidental fires.

CONCLUSION

- ***Irrespective of the drivers, the overall reduction in fires and related particulate matter emissions in 2020 compared to 2019 (0.26Tg in South Asia and 1.11Tg in Southeast Asia) had a positive environmental impact, with less pollution in some South/Southeast Asian countries.***