Are policy-driven timing shifts in crop residue burning worsening air quality in North India?

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Air pollution and health metrics

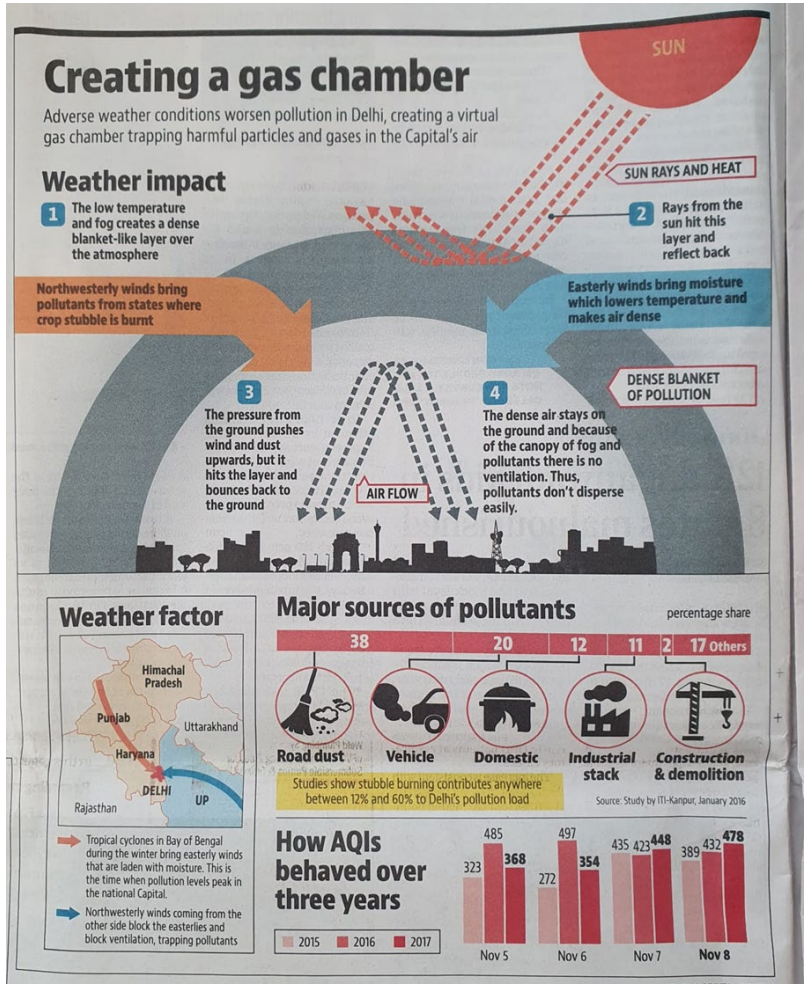
- 22 of the top 30 most polluted cities globally are located in India [IQAir world air quality report, 2020]
- India has a disproportionately high mortality and disease burden due to air pollution
- Second largest risk factor contributing to disease burden after malnutrition

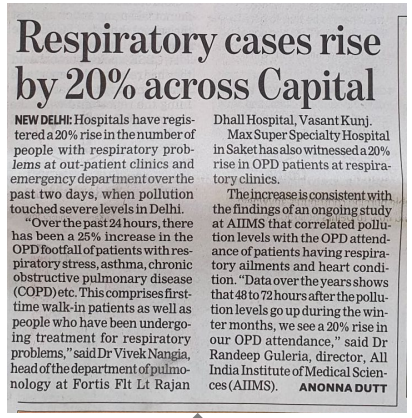
2019 Pollution and Health Metrics – Global, Regional and Country Analysis (Lancet commissioned)
1.24 million premature air pollution related deaths in India in 2017 (household air, ambient particulate and ozone)

Living with smog

Local response: construction ban, "odd-even" vehicles, school closures

Hindustan Times Nov 08 2017





Respiratory cases rise by 20% across Capital

NEW DELHI: Hospitals have registered a 20% rise in the number of people with respiratory problems at out-patient clinics and emergency department over the past two days, when pollution touched severe levels in Delhi.

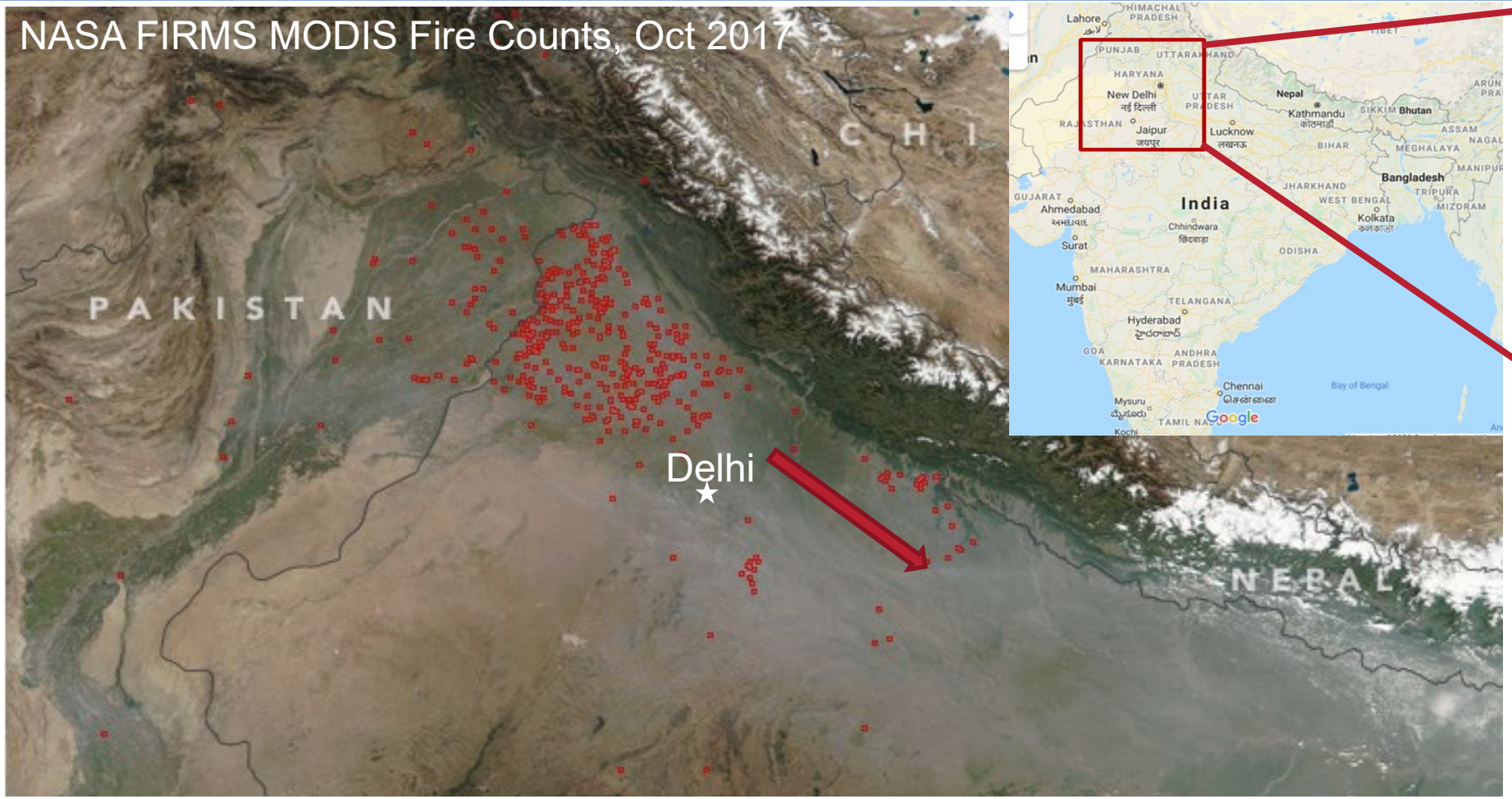
"Over the past 24 hours, there has been a 25% increase in the OPD footfall of patients with respiratory stress, asthma, chronic obstructive pulmonary disease (COPD) etc. This comprises first-time walk-in patients as well as people who have been undergoing treatment for respiratory problems," said Dr Vivek Nangia, head of the department of pulmonology at Fortis Flt Lt Rajan Dhall Hospital, Vasant Kunj.

Max Super Specialty Hospital in Saket has also witnessed a 20% rise in OPD patients at respiratory clinics.

The increase is consistent with the findings of an ongoing study at AIIMS that correlated pollution levels with the OPD attendance of patients having respiratory ailments and heart condition. "Data over the years shows that 48 to 72 hours after the pollution levels go up during the winter months, we see a 20% rise in our OPD attendance," said Dr Randeep Guleria, director, All India Institute of Medical Sciences (AIIMS). ANONNA DUTT

25 % increase in patients with respiratory stress over a 24-h period

Post-monsoon smog in North India



Region of significance -

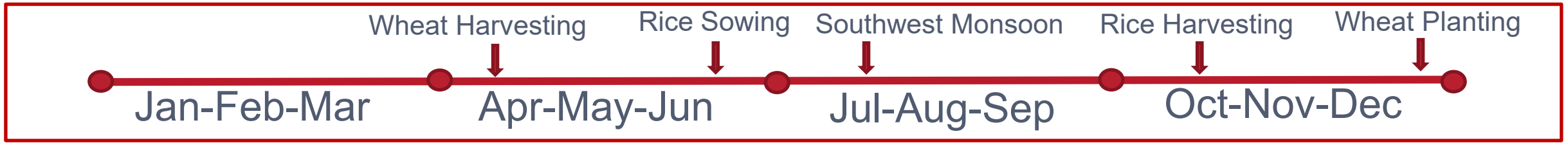
- Breadbasket of India
- Hundreds of millions of inhabitants
- Large rural populations

Major contributors: Coal burning for thermal power production, industry emissions, construction activity and brick kilns, transport vehicles, road dust, residential and commercial biomass burning, domestic waste burning, & crop residue burning (CRB)

Photo Credit: Ravindra Khaiwal, PGI

Farmer Challenges I

The rice-wheat cropping system



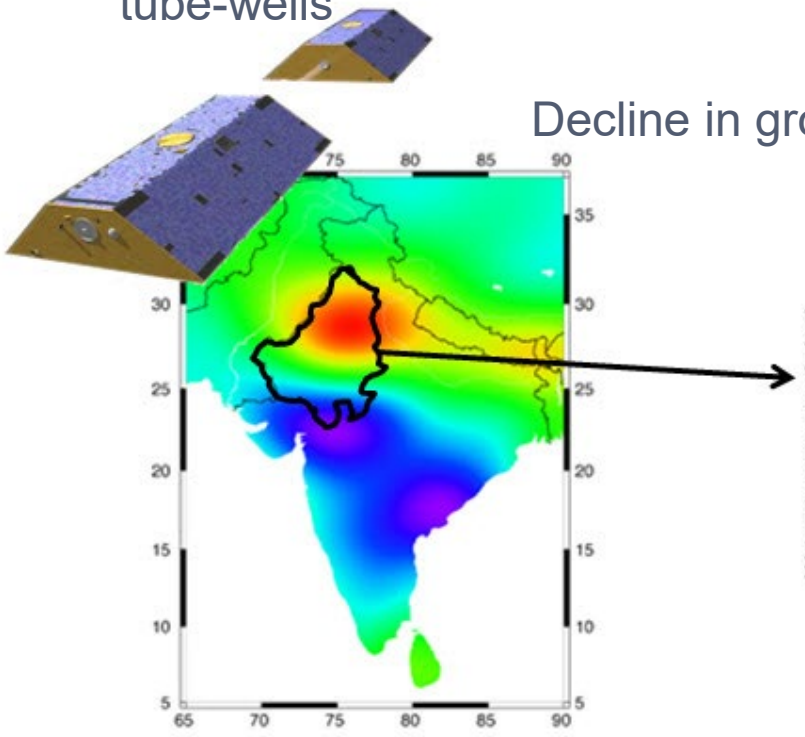
- *Mega-tonnes of leftover rice stubble*
- *High silica content & difficult to break down so not used as animal fodder*

Source:https://www.theguardian.com/world/2019/nov/08/indian-farmers-have-no-choice-but-to-burn-stubble-and-break-the-law

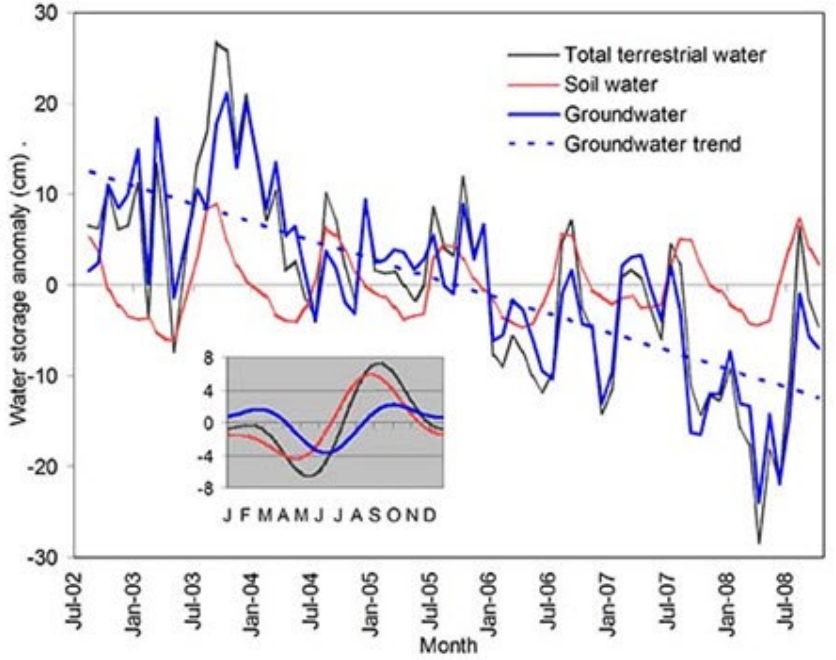
- *Tight time constraints - fields rapidly cleared to plant wheat crops*
- *Cheapest solution is to burn which emits smoke & $PM_{2.5}$*

Farmer Challenges II

- Excessive groundwater extraction for irrigation has led to a water crisis in the Northern Indian states
- ‘Green Revolution’ drove agricultural intensification -> adoption of a high yield dual rice-wheat cropping system
- Actively supported by Government initiatives such as a minimum support price, free electricity to run irrigation tube-wells



Decline in groundwater storage [Rodell et al, 2009]



Agricultural Policy

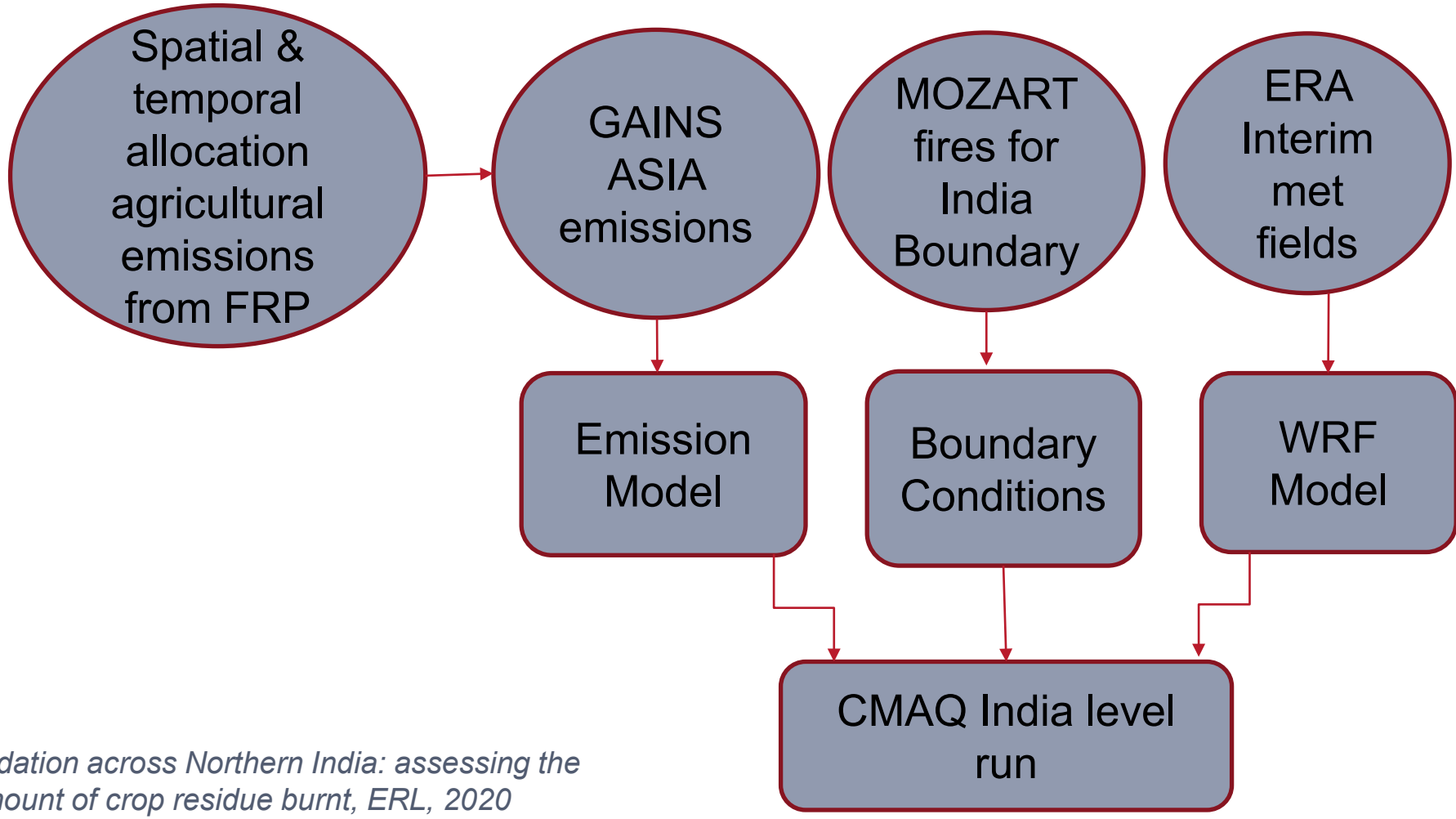
- In 2009, local governments issued the “Sub-Soil Water Act” (SSWA) to reduce the reliance on groundwater irrigation
- Altered the prescribed timing of rice planting - moved closer to the onset of the monsoon
- Farmers began to sow rice in late-Jun as opposed to Apr/May

NASA GRACE https://www.nasa.gov/topics/earth/features/graceImg20091214.html

Unintended consequences of agricultural policy?

- Recent studies suggest this policy – **primary contribution to the increasingly severe air pollution crisis engulfing North India**
- Delayed rice planting -> delayed residue burning
- Burning, stable post-monsoon conditions (late-Autumn/winter) & reduced meteorological ventilation -> more conducive to the formation of poor air quality

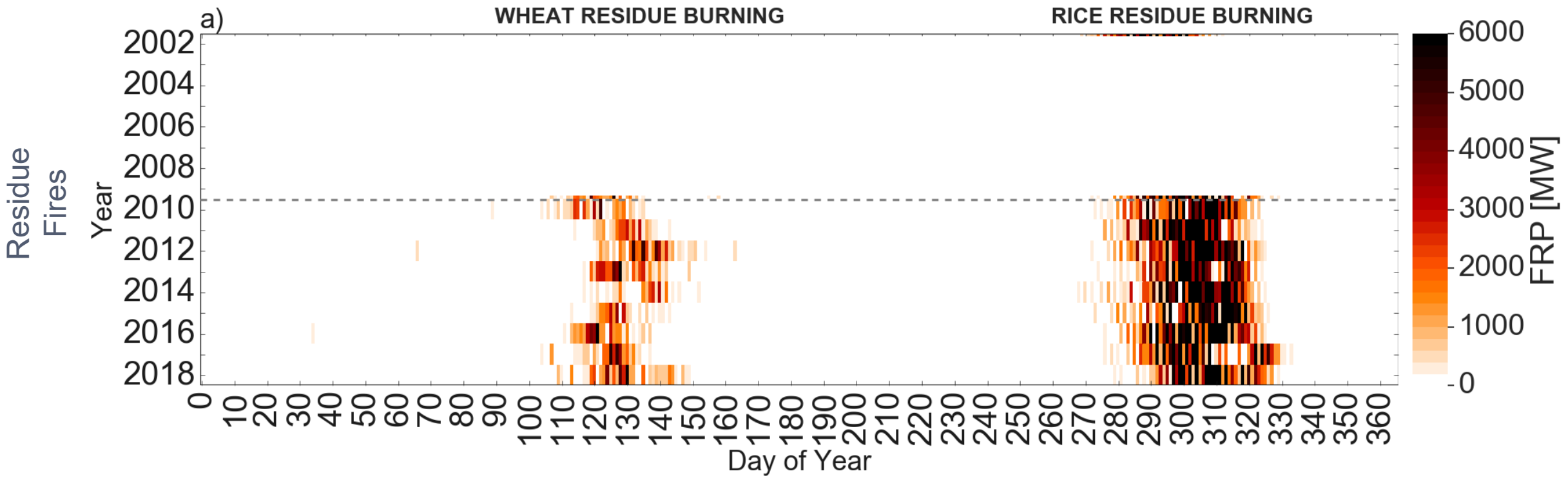
We combined VIIRS (375m) fires with air quality modelling to test if timing shifts in CRB has amplified North India air pollution



Sembhi et al., Post-monsoon air quality degradation across Northern India: assessing the impact of policy-related shifts in timing and amount of crop residue burnt, ERL, 2020

Long-term changes in CRB and vegetation

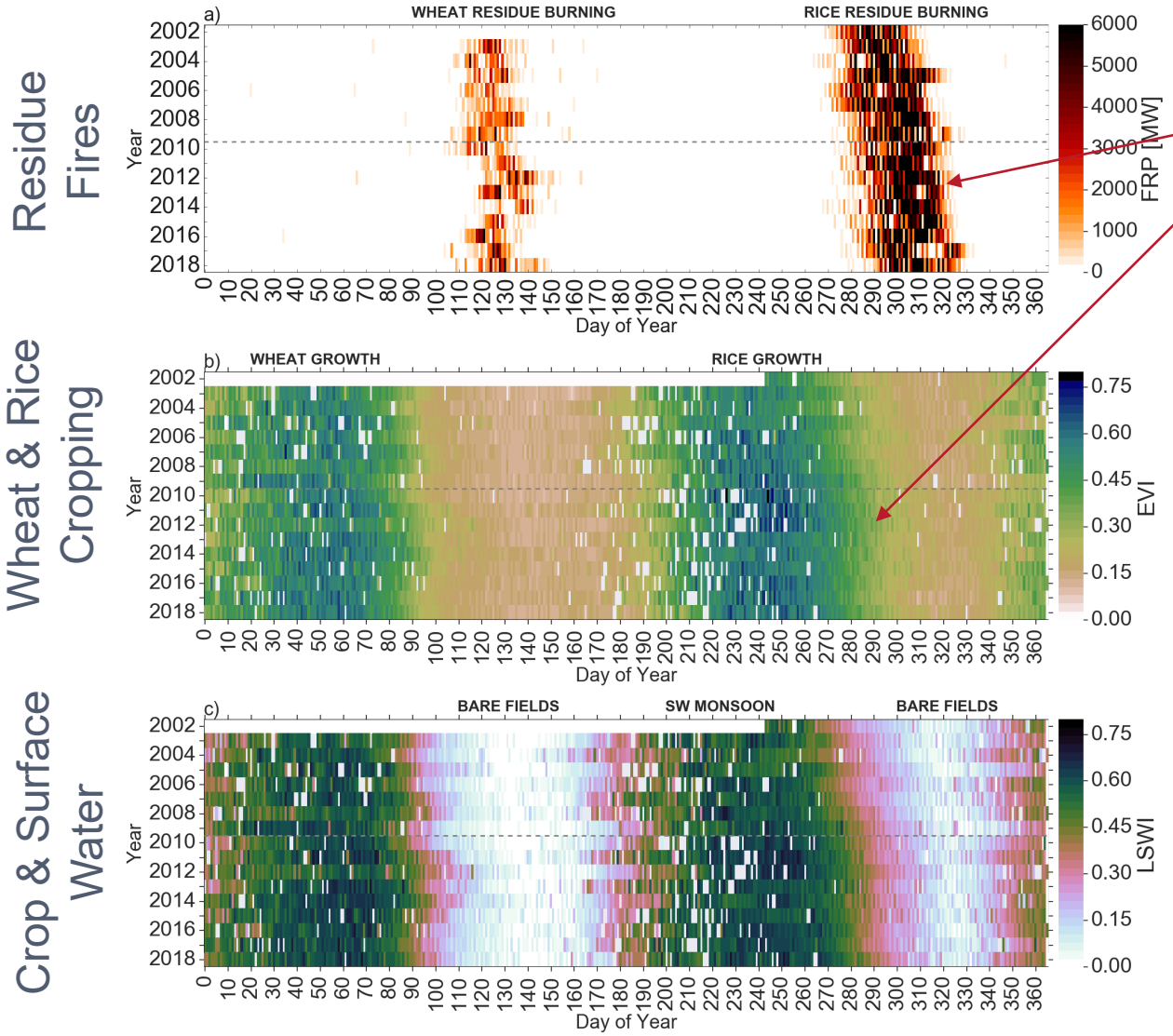
MODIS time series active fires



MODIS FRP average –for the Northwest agricultural state of Punjab

Long-term changes in CRB and vegetation

MODIS time series active fires & vegetation indices

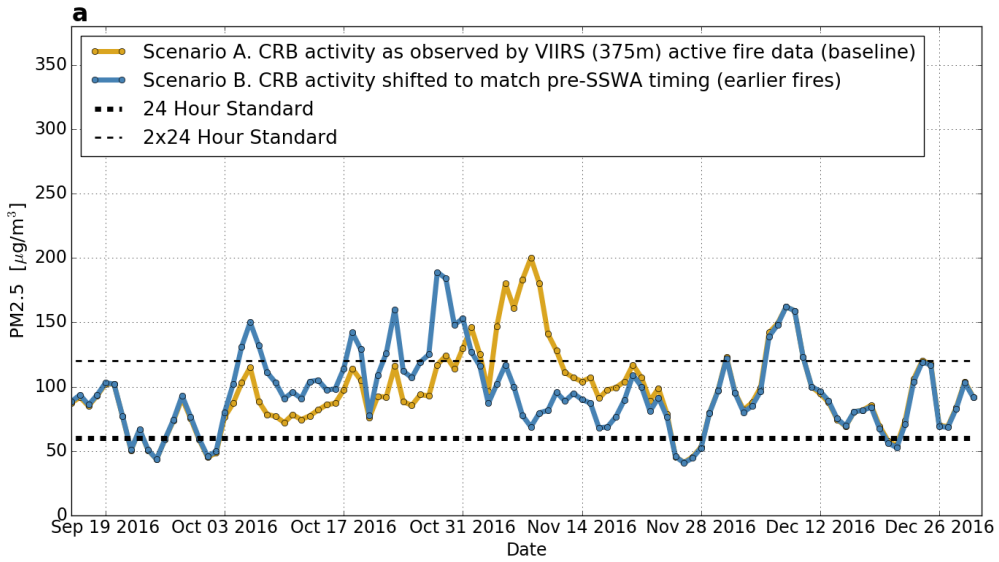


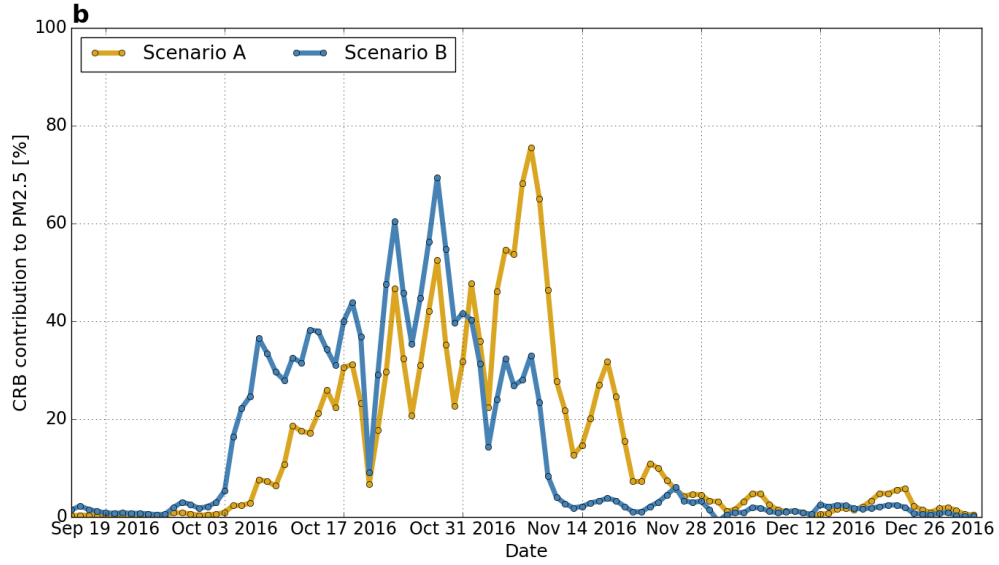
Approx. ~ 10 day shift in rice harvesting and the peak signature of rice residue burning since policy was introduced

Simulations:

- Fixed emission sources (industry, vehicular etc.) except for fires (VIIRS 375m)
- Baseline scenario: 2016
- Early fire scenario (pre-policy enactment)

Contribution of agricultural fire emissions on Delhi $PM_{2.5}$

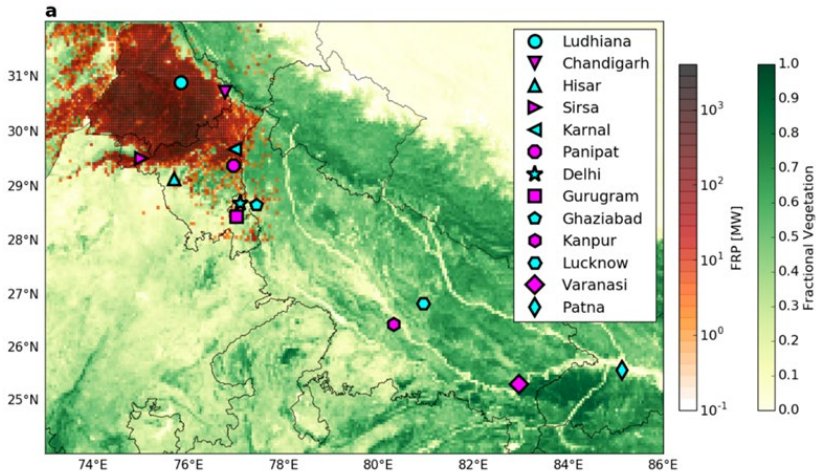




40% CRB contribution to $PM_{2.5}$ concentrations in Delhi for 2016

Pre- and post-policy
Similar $PM_{2.5}$ in baseline and early fire scenarios

VIIRS FRP for Oct to Nov 2016

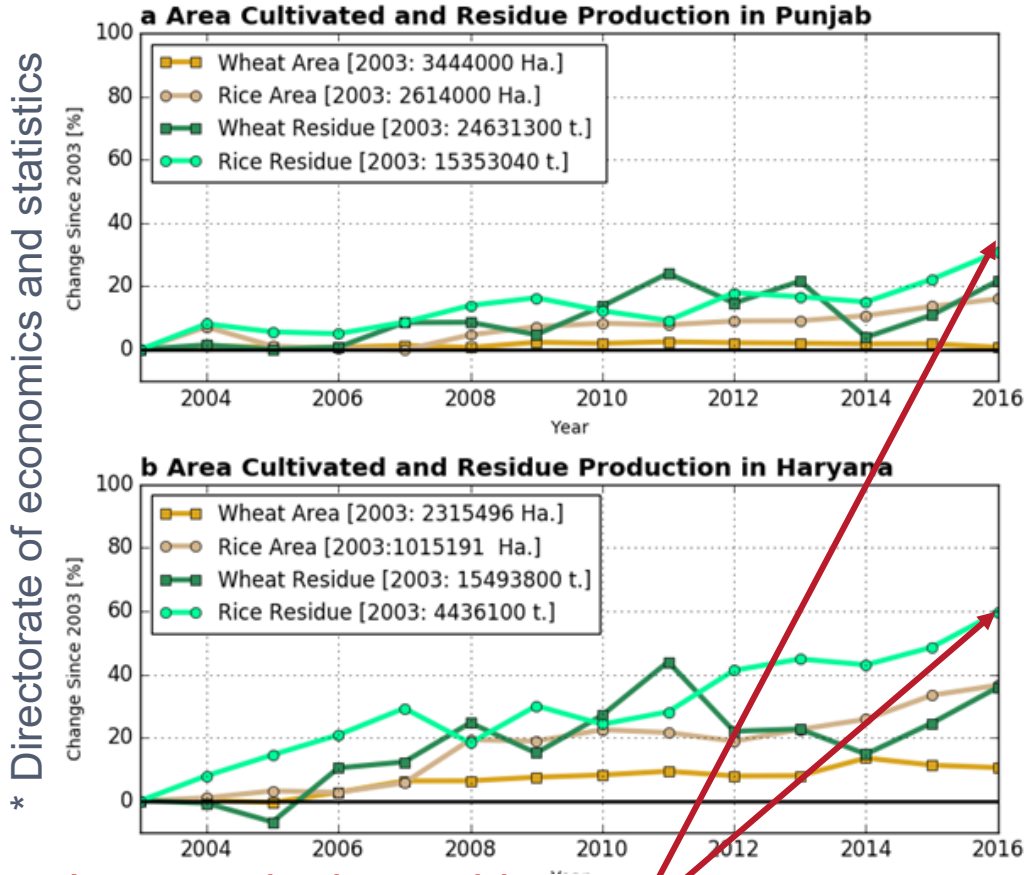


Future delays to harvesting and burning -> could potentially lead to more intense $PM_{2.5}$ concentrations in Delhi – in certain meteorological conditions

Varied (reduced) fire emissions & fixed meteorology *(despite timing of fires)*

Fixed fire emissions & varied meteorology *(despite timing of fires)*

What is driving this behaviour?



Increase in rice residue production since 2003

Agricultural Intensification, the sheer amount of rice residue, the corresponding number of fires and local meteorology [in agreement with Jethva[1] et al 2019]

Key Outcomes: Post-monsoon air quality has some sensitivity to timing shifts of fires - signals are dominated by the amount of residue burned and meteorological regime

Correlation not causation -unpick drivers using with an air quality model

1 Jethva et al, Connecting Crop Productivity, Residue Fires, and Air Quality over Northern India, Nature Sci. Rep, 2019

The way forward

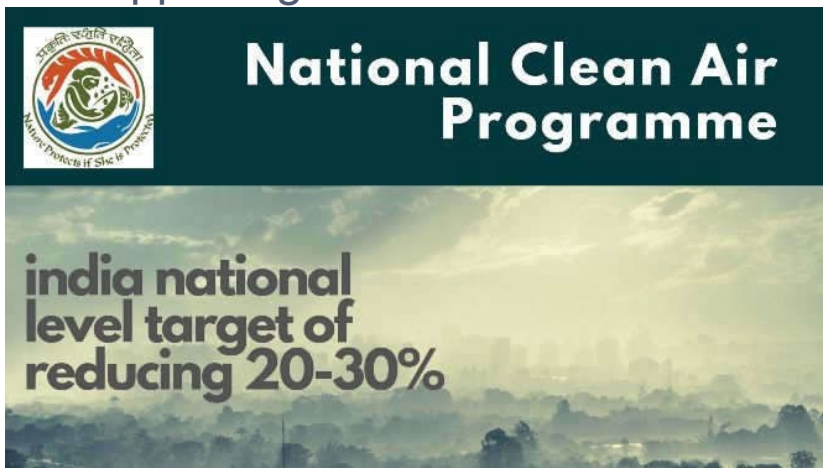
Recommendations:

- Implement adequate systems for the collection, storage and processing of agricultural residues into biofuel to replace more polluting fuels in energy generation
- Avoid further policy-driven delays to rice sowing dates until largescale uptake of CRB alternatives
- Dialogue between pollution & agricultural policy makers to avoid potential unintended consequences

Consulting Gov. policy-makers

Raising awareness with farmers

Supporting national AQ missions



Current Gaps:

1. *Products on non-agricultural fires (landfill fires, burning on roadside etc.) would be very helpful to improve current Indian emission inventories*
2. *More validation of agricultural fires - ground truthing fieldwork conducted by Punjab Remote Sensing Centre*

Thank you for your time and attention.

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GCRF Global Challenges Research Fund

BRITISH COUNCIL

UKIERI UK-India Education and Research Initiative

UKRI Research England

Key Points

- EO can provide material evidence to **underpin government policies** and help determine their effectiveness
- Provide **new scientific insights into the impact of crop residue burning** on air quality and human health
  - *Separate factors connected to each other, test uptake of policy, pollution exposure far from the pollution source region*
- Products on non-agricultural fires (landfill fires, small fires in city) would be very helpful to improve Indian emission inventories

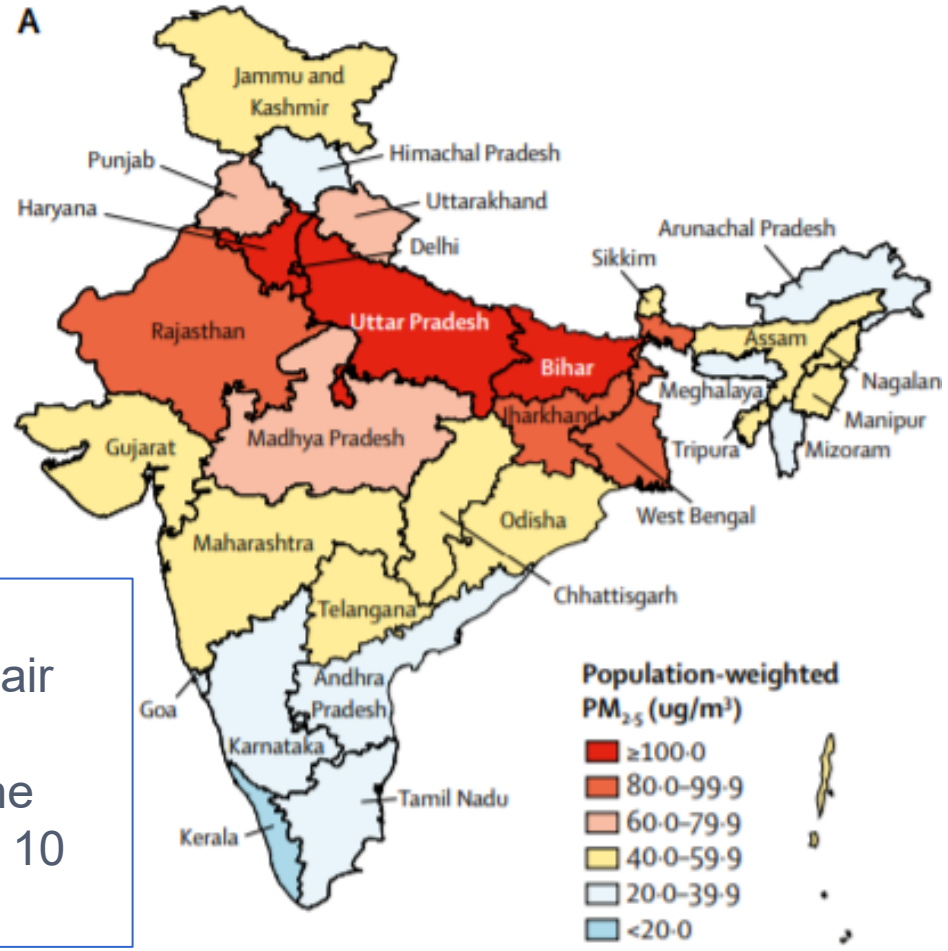
Lessons learnt

- **Correlation is not causation** – *go beyond just correlating different EO datasets. Model allowed us untangle complexity of the problem i.e. keeping other emissions sources constant (e.g. vehicular) and modify the fires only*

- **Policy impacts** –*positive and/or negative, may be evident years after enactment. Be mindful of this when designing policy advice from satellite observations and consult different sectors (i.e. health) where necessary.*

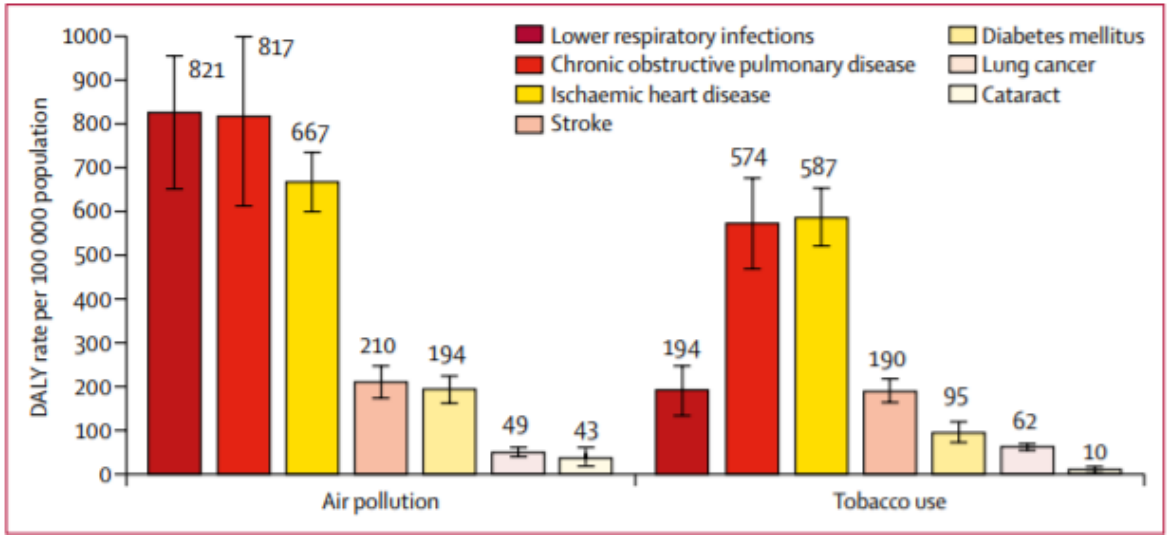
Air pollution and health metrics

Population-weighted mean ambient air $PM_{2.5}$



WHO annual air quality guideline value = 10 µg/m^3

DALY rates attributable to air pollution and tobacco use in India



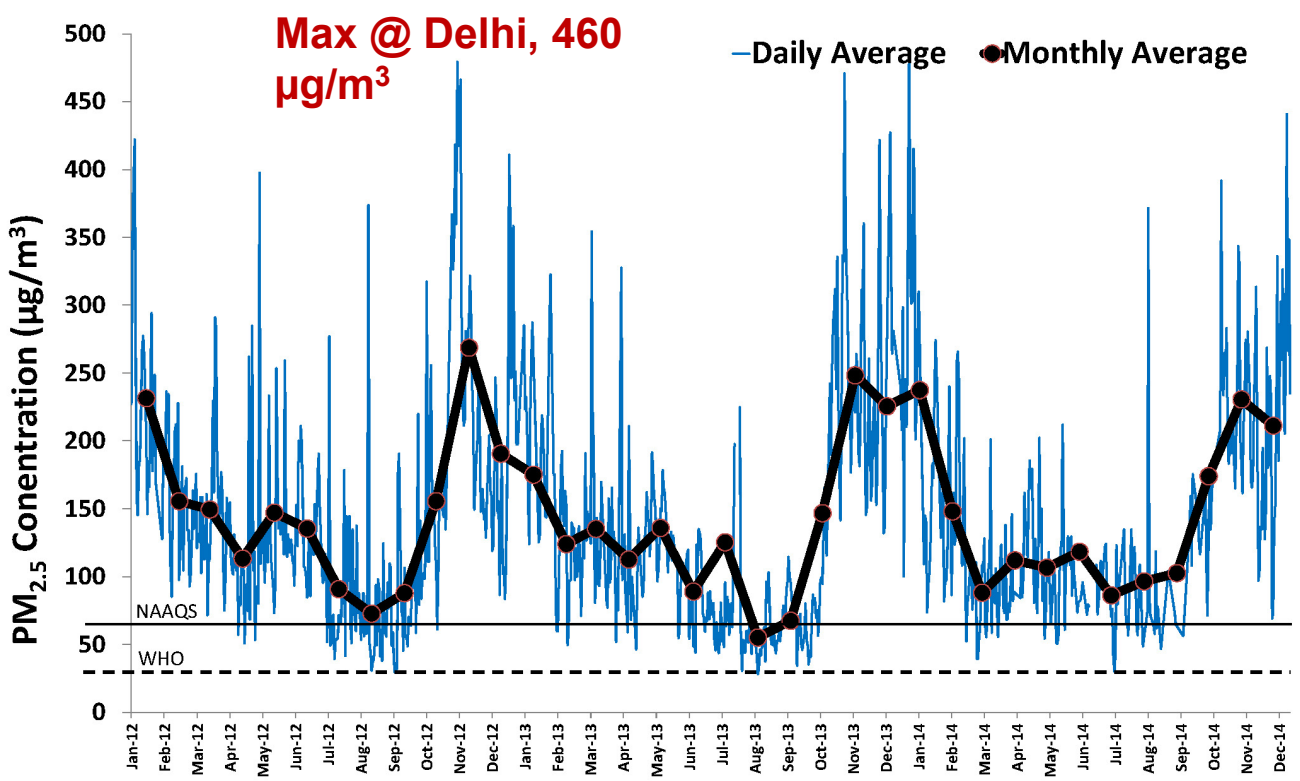
Disability Adjusted Life Years = measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death

- 76.8% of population of India – exposed to annual exposure population-weighted mean $PM_{2.5}$ of 40 µg/m^3 or greater
- India contributed to 18.1% of global population but had 26.2% & of global air pollution DALYS in 2017

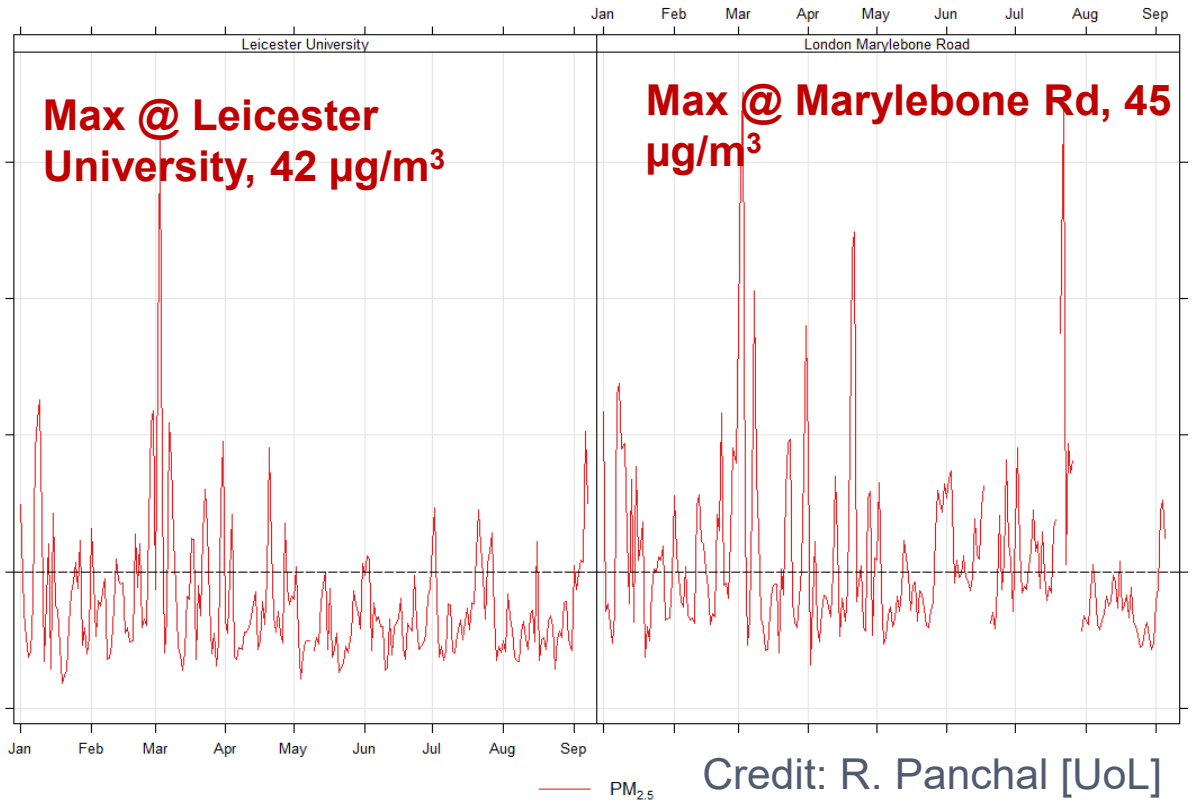
Sources: [1] Balakrishnan & Collaborators, Impact of air pollution on deaths, disease burden and life expectancy across Indian States: GBD 2017, The Lancet, 2018, **[2]** Pandey & Collaborators, Health and economic impact of air pollution in the states of India: GBD2019 The Lancet, 2020

Ambient particulate matter pollution in Delhi

Ambient $PM_{2.5}$ for Delhi measured at 4 locations



Ambient $PM_{2.5}$ measured in the UK 2021



Credit: R. Panchal [UoL]

Major contributors: Coal burning for thermal power production, industry emissions, construction activity and brick kilns, transport vehicles, road dust, residential and commercial biomass burning, domestic waste burning, & crop residue burning (CRB)

The Way Forward

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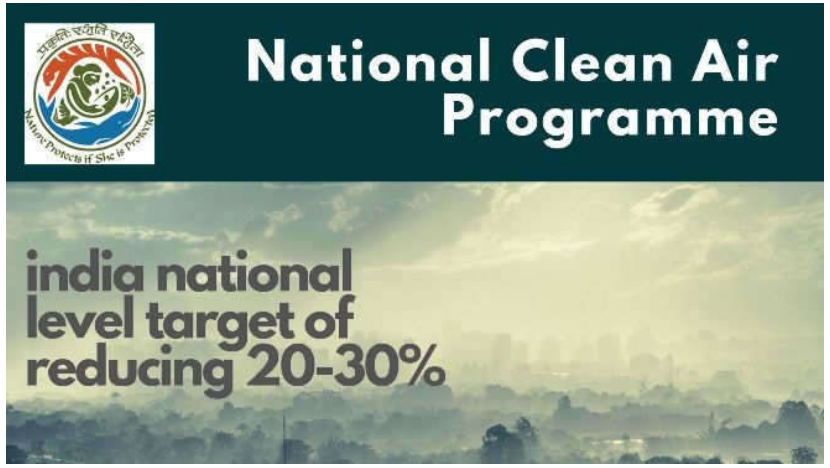

Dissemination to stakeholders, awareness campaigns with farmers, advising decision-makers

India's flagship National Clean Air Programme (NCAP) aims for 30% reduction in air pollution by 2024 (compared to 2017) - huge effort to set up support systems for farmers to make use of residue burning alternatives (e.g. Happy Seeder, Super Straw Management Systems)

Source: https://www.care4cleanair.com/awarnessmaterial Ravindra et al., Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emission, Journal of Cleaner Production, 2019