Bending agricultural burning trajectories: a mixed methods approach in rice-wheat systems of E. India

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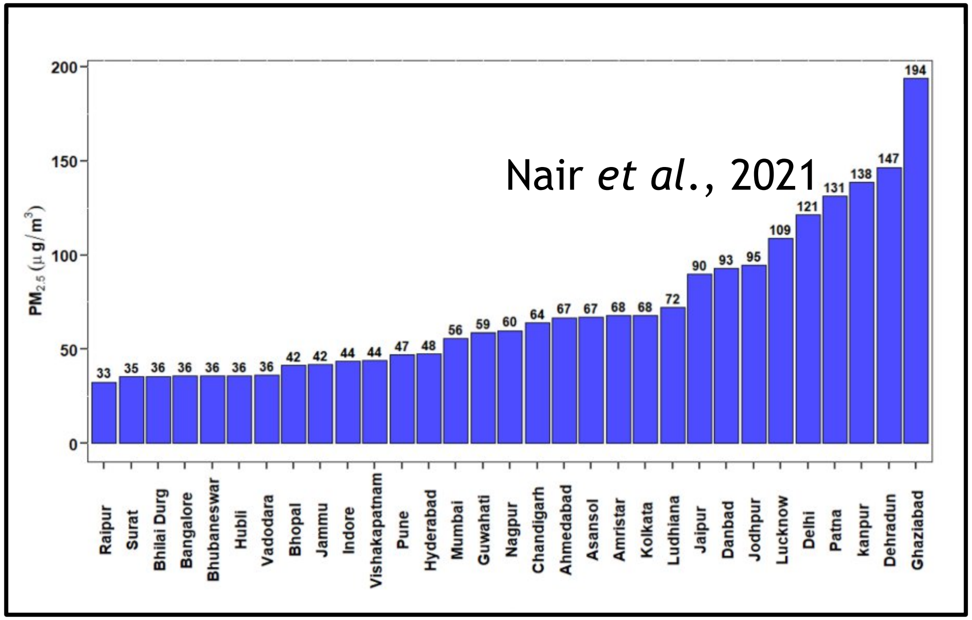
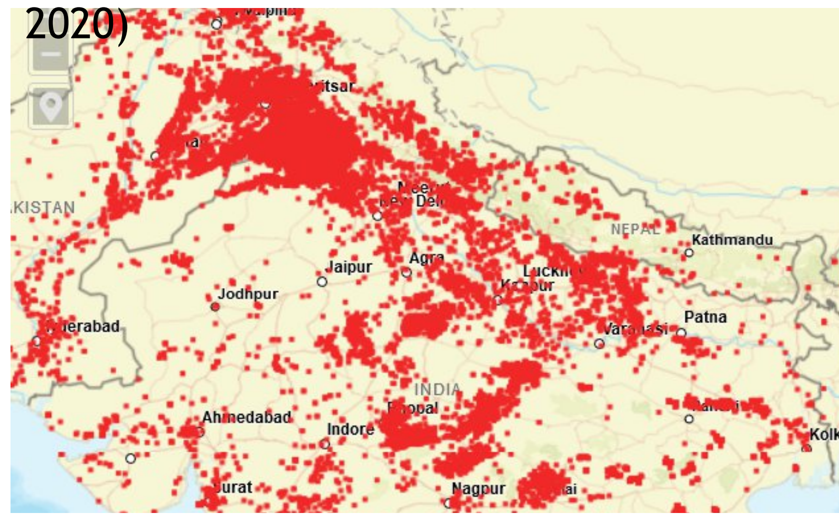
Context: Growing public health crisis from poor air quality in India

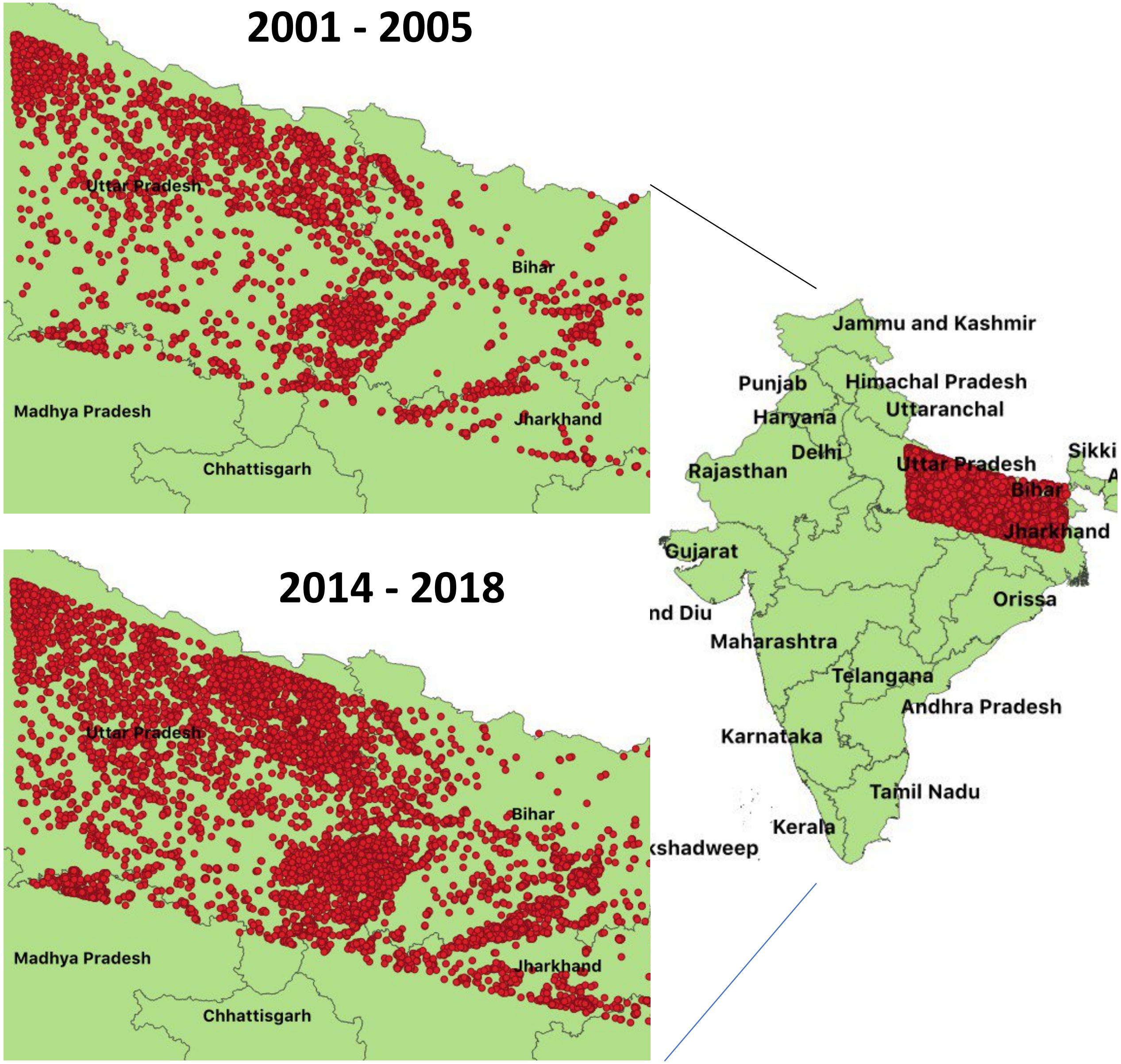


31 'nonattainment' major metropolitan areas in India, with little progress on abatement despite high-profile policy initiatives (e.g. NCAP 2019)

Snapshot: 2 weeks during the peak of rice straw burning (Nov. 15-Nov. 30, 2020)



Residue burning contributes ~42% of particulate air pollution during the late fall and early winter 'peak' in Delhi – Bikkina *et al.*, 2019



Burning occupies 'only' 9% of the rice cultivated area in E. India, should we worry? ~250% increase since early 2000s

Development challenge: tech 'lock in' can transform emerging trends into 'wicked' problems

Research questions:

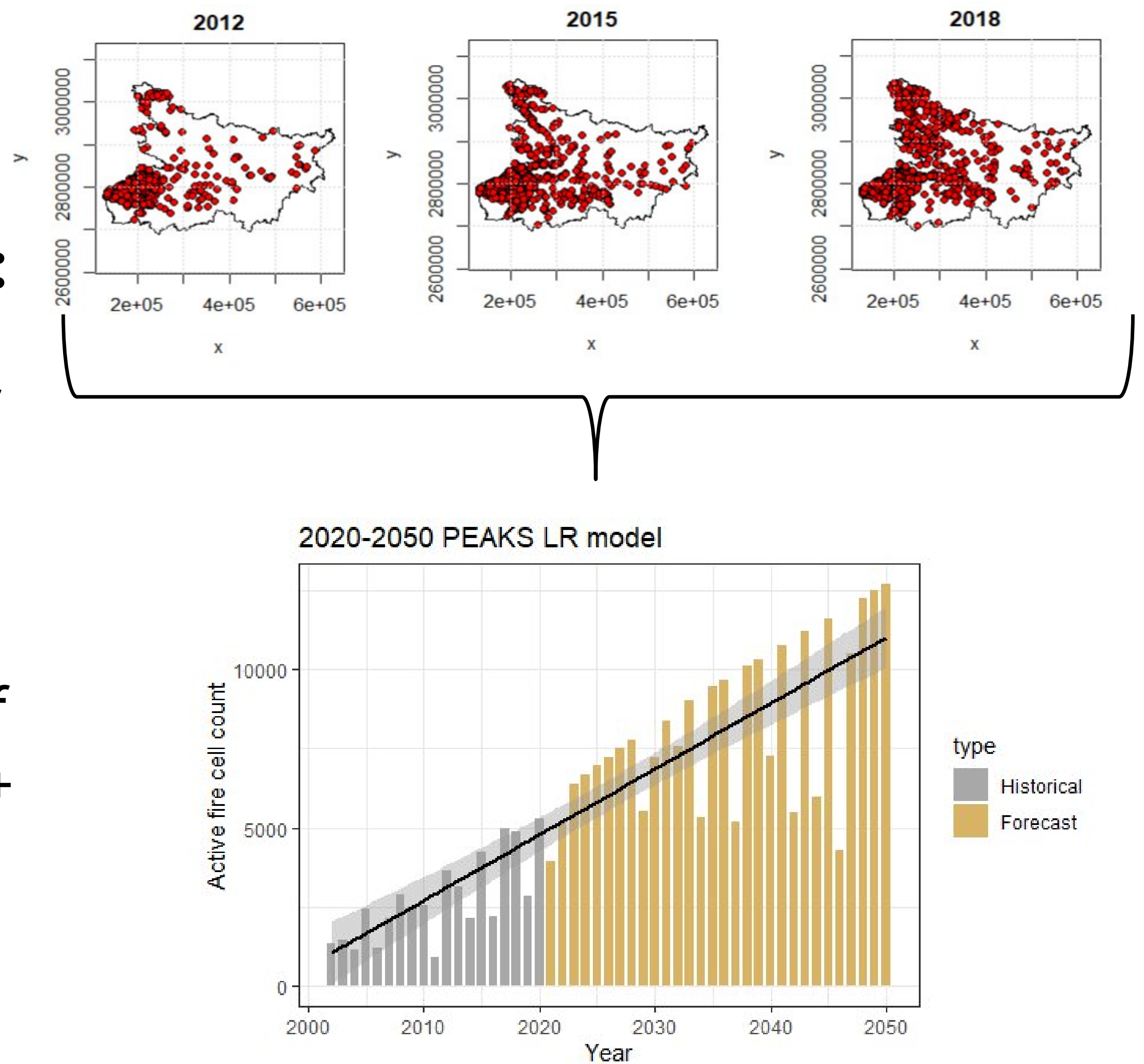
Q1: What are the range of plausible futures and ecosystems disservices associated w/ current burning trajectories?

Q2: What are the implications of alternative development pathways? (i.e. fate of residues in the landscape)

Q3: What can be done to 'bend' trajectories?

Step 1: Space-time burning predictions from satellite data

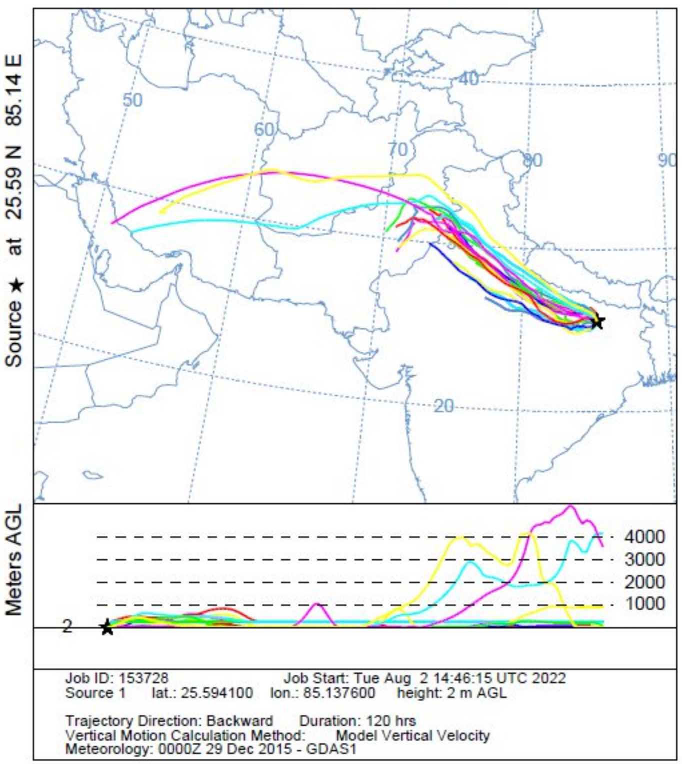
Quantifying change processes: ‘Naïve’ point pattern analysis of historical MODIS fire data used to develop an empirical model of change (diffusion + random elements) with forecasts generated to 2050

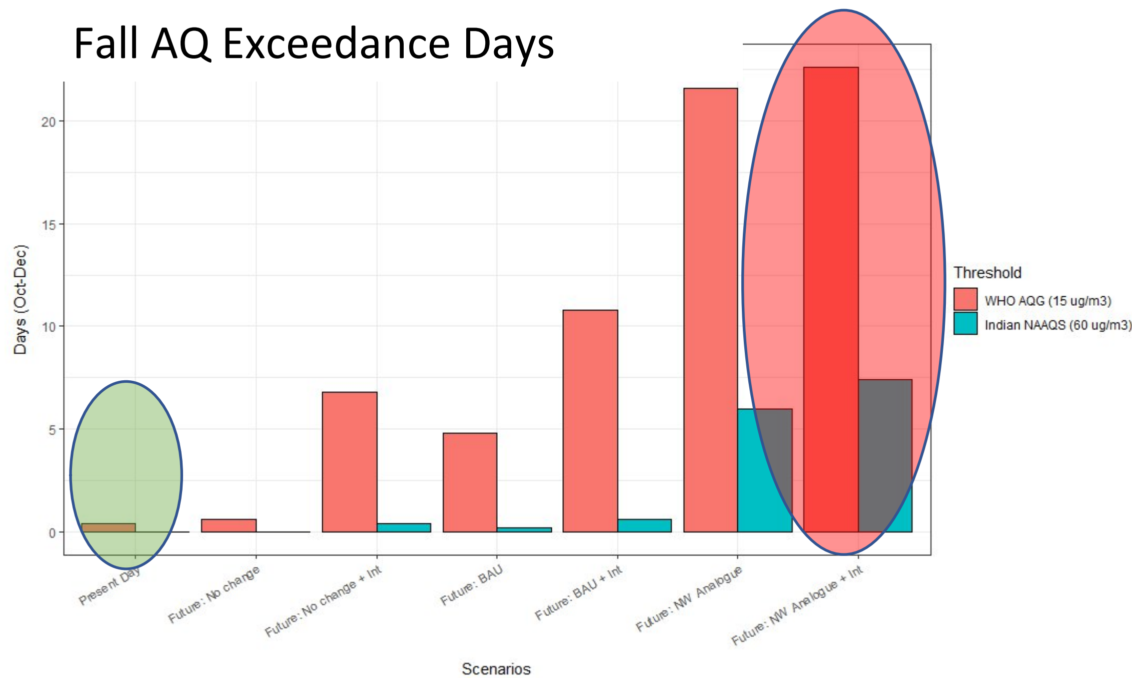


Step 2: Estimating AQ impacts with atmospheric transport modeling

Scenarios of change and public health ($PM_{2.5}$ exceedance days) in Patna, Bihar in 2050 from residue burning alone:

- No change (+ crop intensification)
- Business-as-usual (+ crop intensification)
- Northwest analogue (+ crop intensification)





Worst case: ~1/3 of the days exceed WHO standards for $PM_{2.5}$

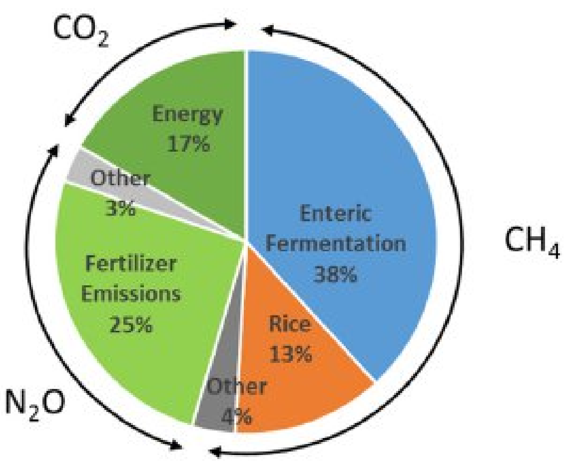
Status quo: burning as a minor contributing factor to AQ

Community Earth System Model - CESM2.1.0

Step 4: GHGs + the fate of rice crop residues

Rice residue

S1	S2	S3	S4	S5
Burn (*in situ*)	Soil Incorporation	CA	Livestock fodder	Biochar

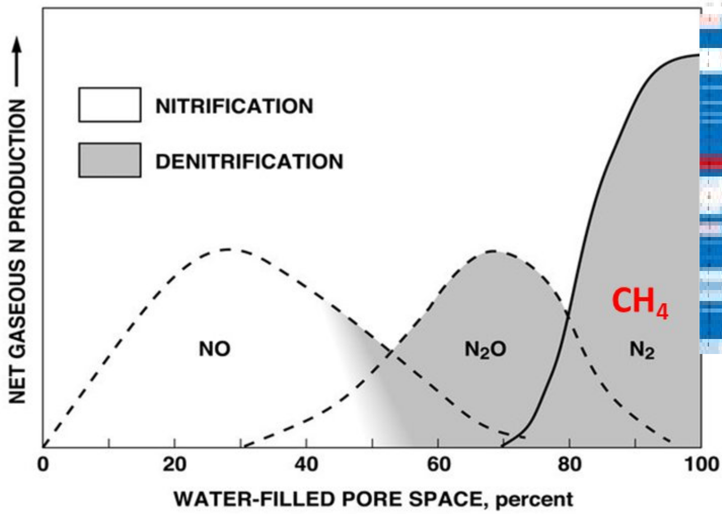


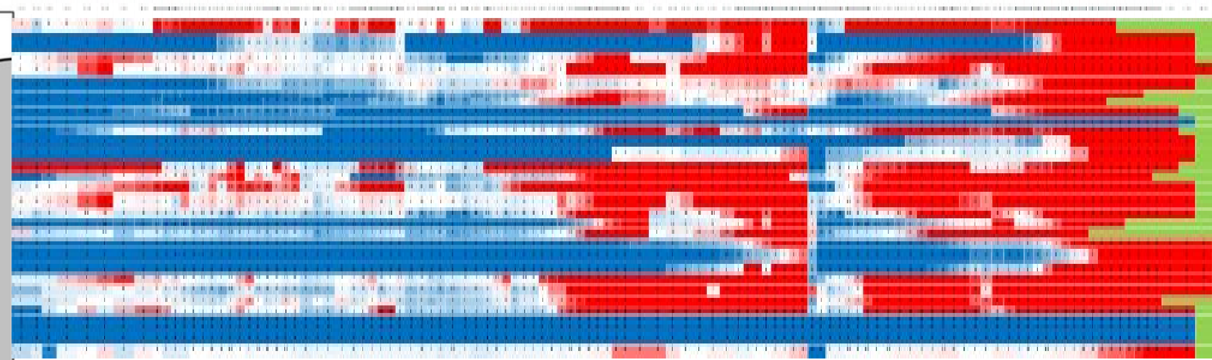
745 Mtons CO_2eq Rao *et al.*, 2019

Half of the land-based GWP in the agri-food systems of India is associated with enteric fermentation and CH_4 emissions from rice. What are the emission costs of different residue end uses (e.g. low quality fodder) and how do they vary by production context?

Regulatory approaches to ban burning have not been successful; possible carbon financing of 'no burn' solutions need to consider a range of counterfactuals. Are there comparatively 'safe' destinations for crop residues that avoid tradeoffs between air quality and GHG emissions?

Production system complexity + GHG estimation





Continuity of soil inundation in 28 rice field across a single district in E. India; dark blue Indicates presence of ponded water with red indicating fully drained soil conditions.

In complex production environments like rice systems in E. India, **generalized GHG estimates (e.g. rice produces *X* t ha^{-1} CH_4 - 'Tier 1' approaches) don't hold.**

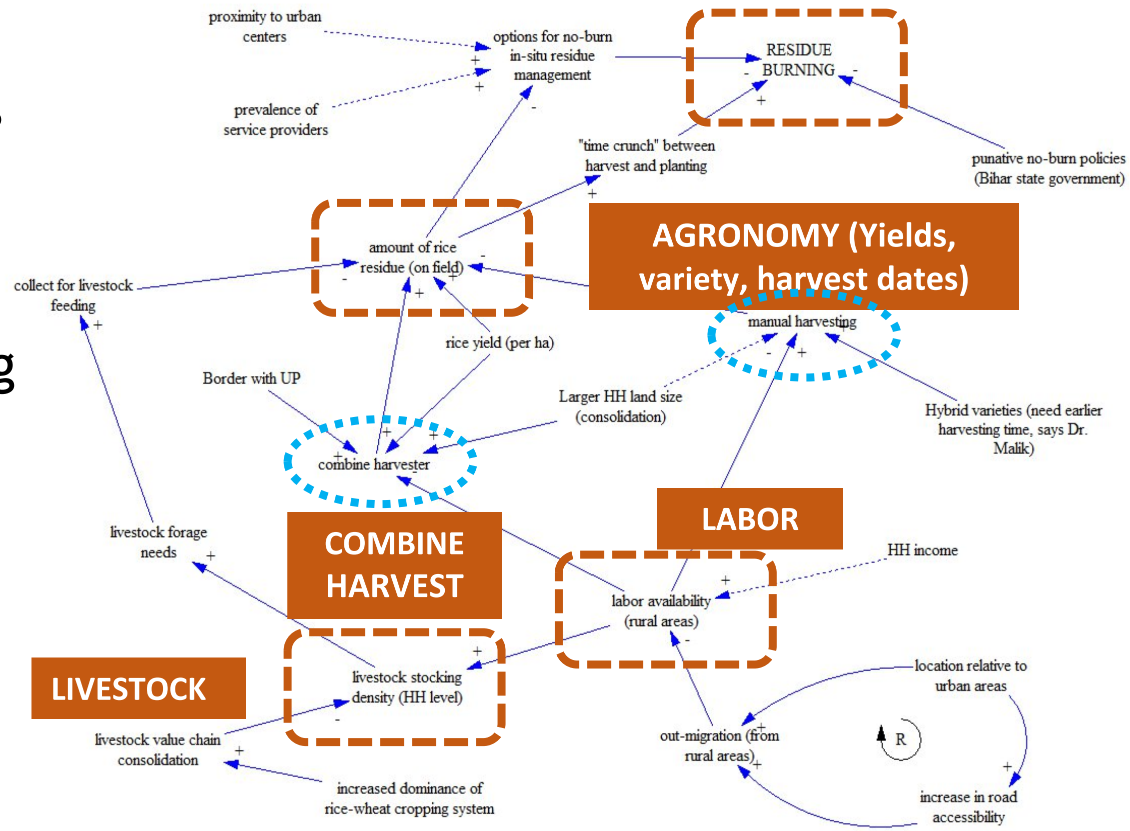
Water (and redox reactions) mediate N_2O and CH_4 emissions. Beyond climate, landscape factors *x* soil *x* management govern field water status.

- Can Tier 3 models like DNDC capture these dynamics?

Step 5: Decision pathways to burning

Labor scarcity and tradeoffs with off-farm livelihood strategies are increasingly recognized as primary drivers of technological change in S. Asia. Mechanization is accelerating and livestock value chains are consolidating w/ declining holdings at the HH level.

HH surveys deployed to understand the intersection of labor, mechanization, and livestock. **What factors change crop residues from a resource to a waste product?**



"When combines come in, when livestock moves out...."

Surveys substantiate labor as the 'master variable', but structural factors still matter

Decreasing hired labor driving combine adoption

- "No laborers are available to harvest [the rice]. All they are going to other cities. They do worse work even than this but they don't work here." - Respondent 13

Decreased HH labor driving reduction in livestock holdings

- "Now almost all families are the nuclear family so they have less members than before and everybody is busy earning money. That is why they don't have sufficient time to look after the animals." - Respondent 5

Burning prevalence is very high in some villages

- "Whomever has animals in their houses, they use [the rice fodder] as their feeds, otherwise, those who don't have animals to feed burn it around 90%. More livestock, less likely to burn." - Respondent 33

Limited government enforcement of no-burn policies

- "No, there are no restrictions, and no one came [to our farm] to see, so we have no fear of anyone (i.e. the government officials)." - Respondent 33

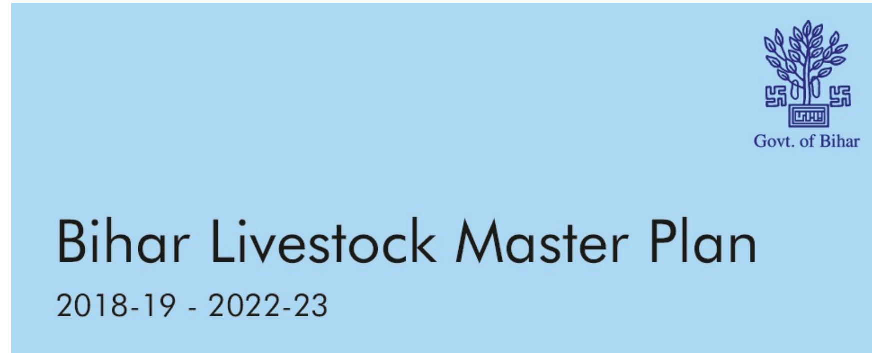
Step 5: Identifying leverage points to bend trajectories towards ‘no burn’ futures

Geographically **strategic investments in processing and marketing infrastructure**, including cold chains, to avoid over-consolidation of industry and crop-livestock decoupling

Buttressed by a burgeoning **carbon offset** market in India

To stimulate additional **technological change** (e.g. straw bailers, H. Seeder)

And facilitate robust local **residue markets** with demand proximate through distributed commercial dairy systems



Many levers, however imperfect – no ‘easy’ answers. Policy engagement planned to blend infrastructure, technology, and market-based approaches.

Predicated on a learning agenda + nimble policy experiments rather than ‘fixed’ re-design. Co-creation of process.

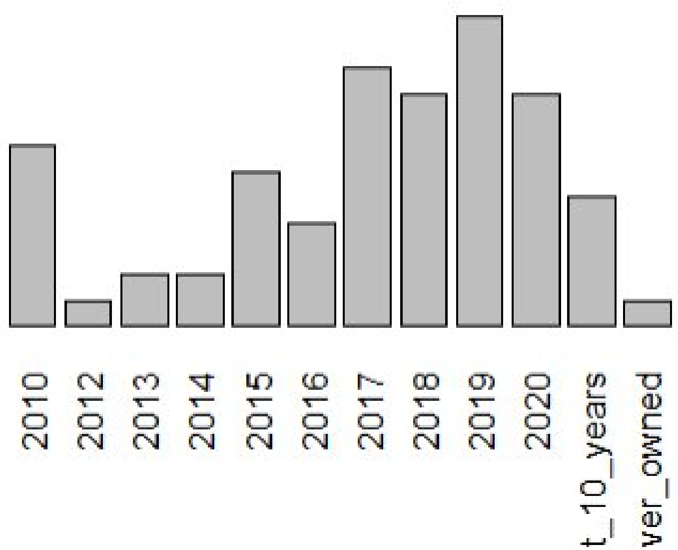
Thank you

Results

Highlights from Round 1

non-livestock owners sell their
l?

le of last animal (Non-livestock owners)



Why did they sell their last anim

X1 <chr>	Count <int>
l.sold.profit	1
l.sold.profit.1	1
l.sold.market	NA
l.sold.straw.comb	1
l.sold.straw.mark	NA
l.sold.labor.hh	34
l.sold.labor.hired	5
l.sold.consum	5
l.sold.cash	23
l.sold.other	13

"Other" write-ins included:

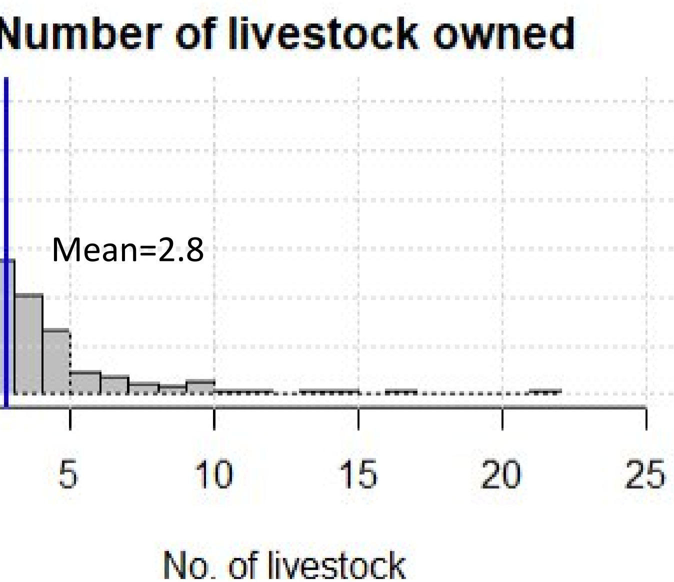
- 5: disease or died
- 1: would not produce milk
- 1: pregnancy issue
- 1: Owner's health was not go
- 5: Change of location and/or (migration)

Results

Highlights from Round 1

HH livestock ownership

of 359 respondents (81%)
ted owning livestock)



45.5%

DECREASE

27.4%

INCREASE

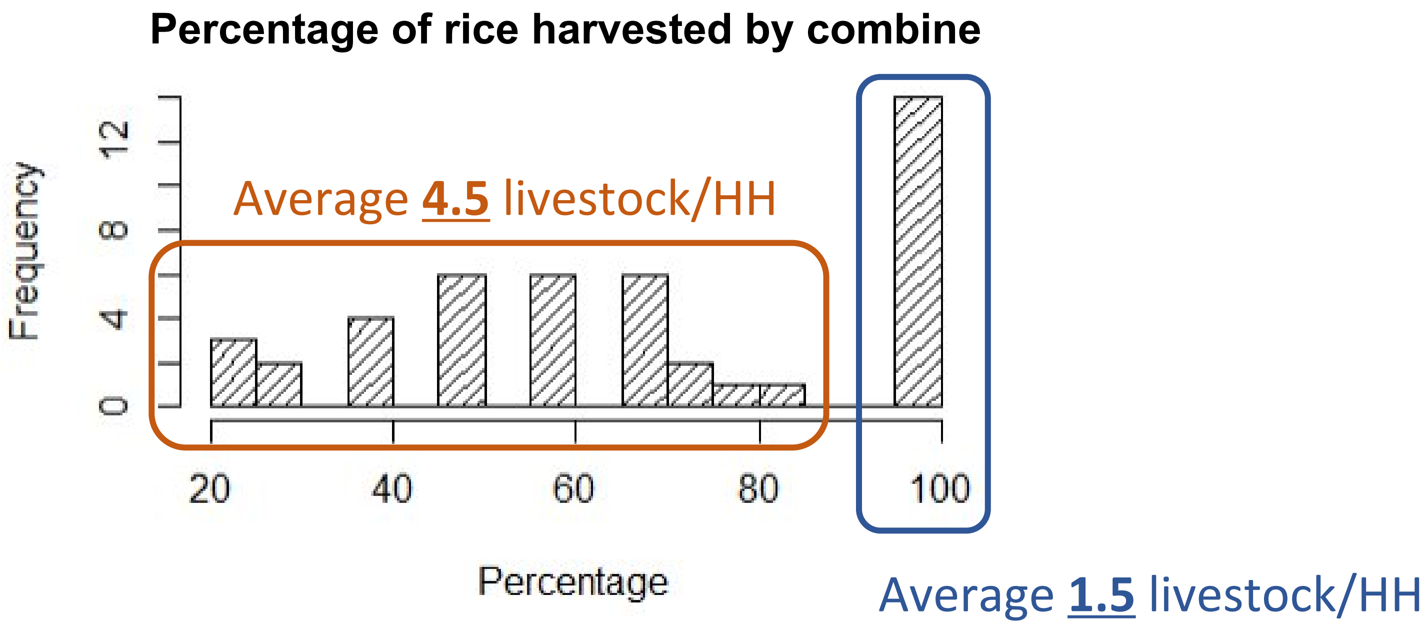
27%

NO CHANGE

Results

Highlights from Round 1

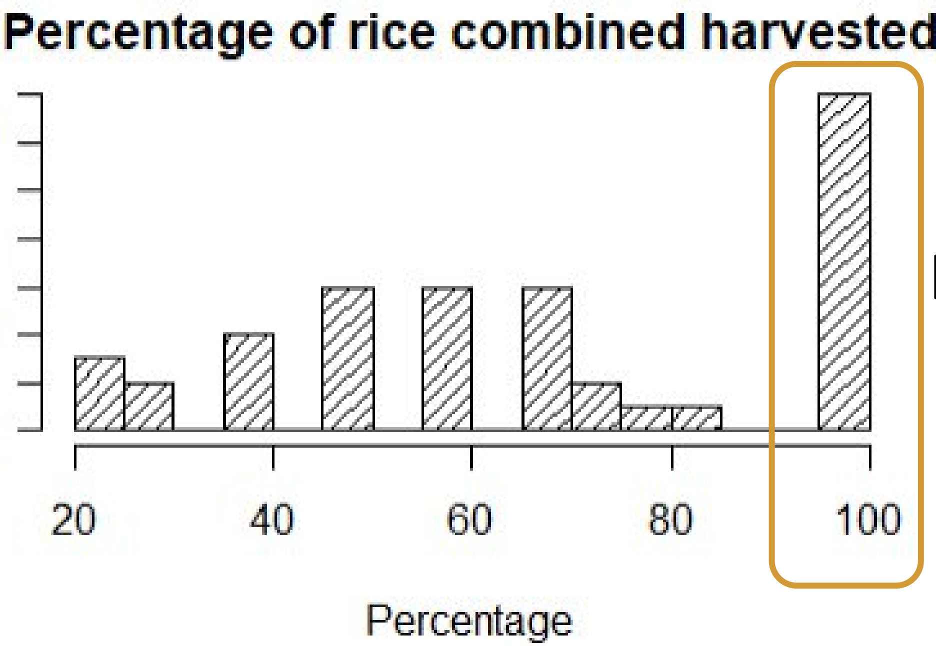
Method (any percentage)	Count	Percentag 360 HHs)
Combine	45	12.5%
Manual	345	95.8%
Reaper	2	0.5%

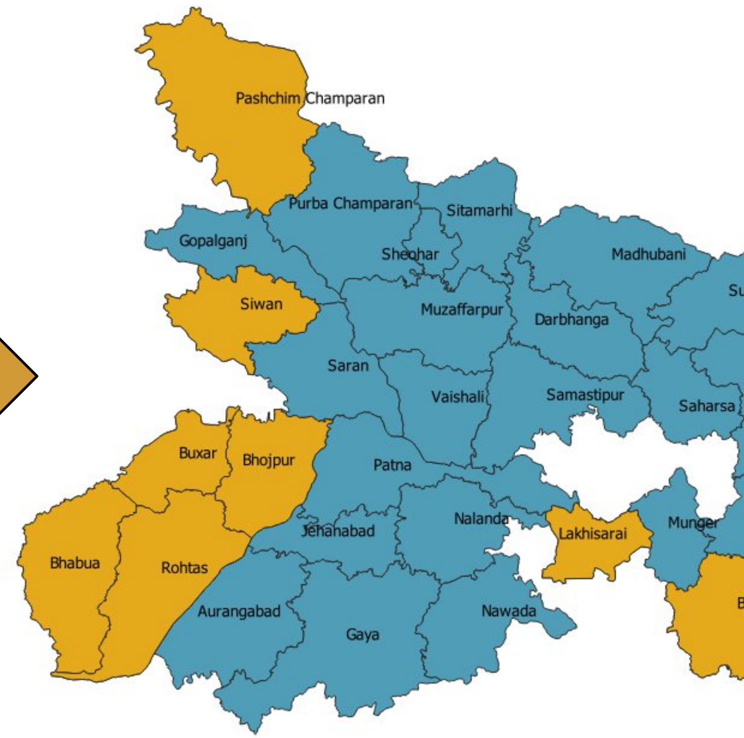


partial adoption?

Majority responded that non-combined fields were ma harvested to **preserve straw for livestock feeding**

Harvest method and livestock holdings





Average livestock ownership for HHs wit
combine usage is **1.5**… lower than the sur
2.8!

not harvest 100% with the combine?

s	No. of respondents
mbined fields were manually harvested to e straw for livestock feeding	24
elds were not accessible by combine (e.g. e, location, etc.)	6
vas sufficient to do manual harvesting in d fields	4
mbined fields were not mature when e was available	0
elds were already harvested when e arrived	1
	2

This group owns on aver livestock, higher than th average (2.8).

This tendency is across t region.