Climate Change and Rice-Wheat System:
Impacts, Adaptation and Mitigation

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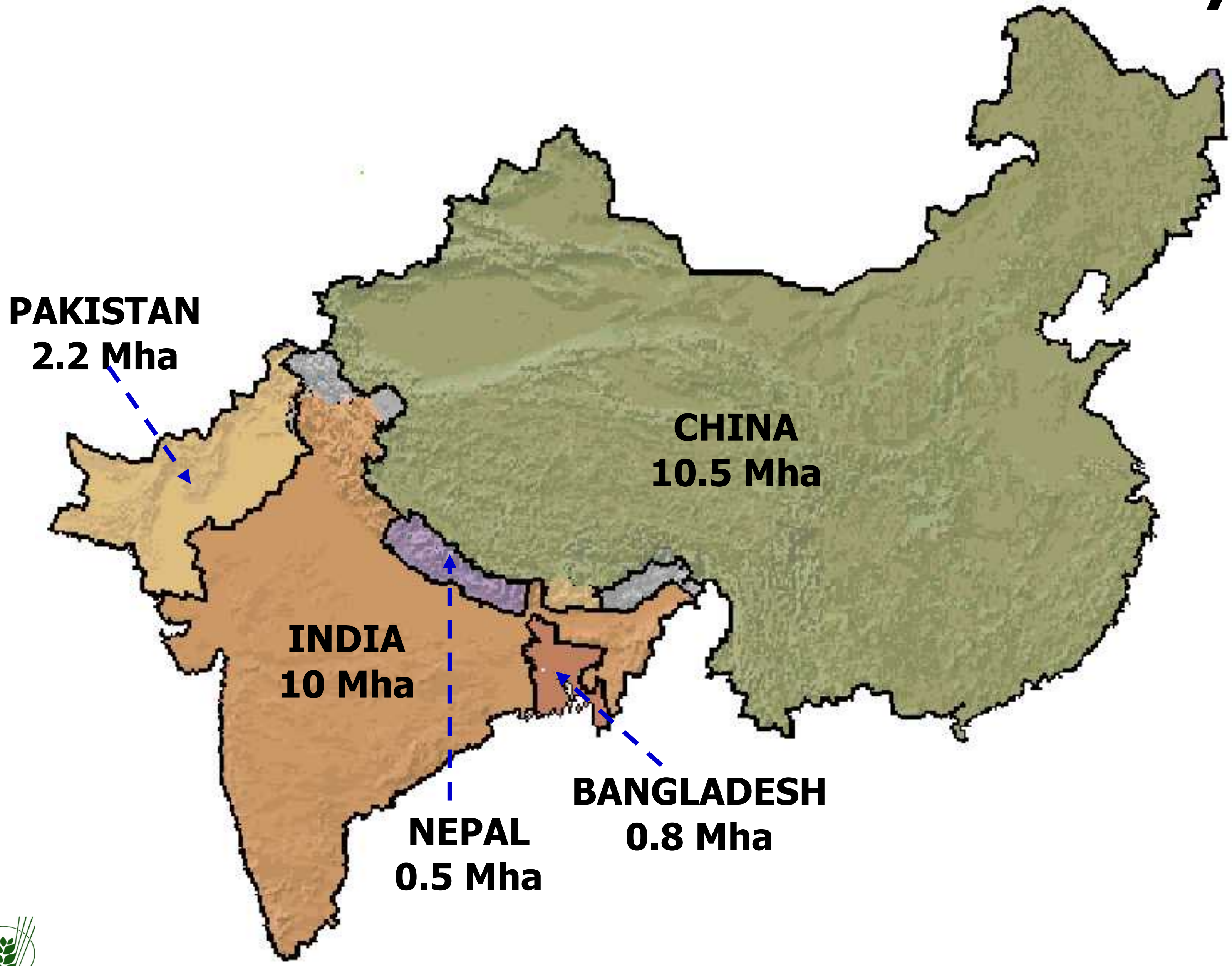
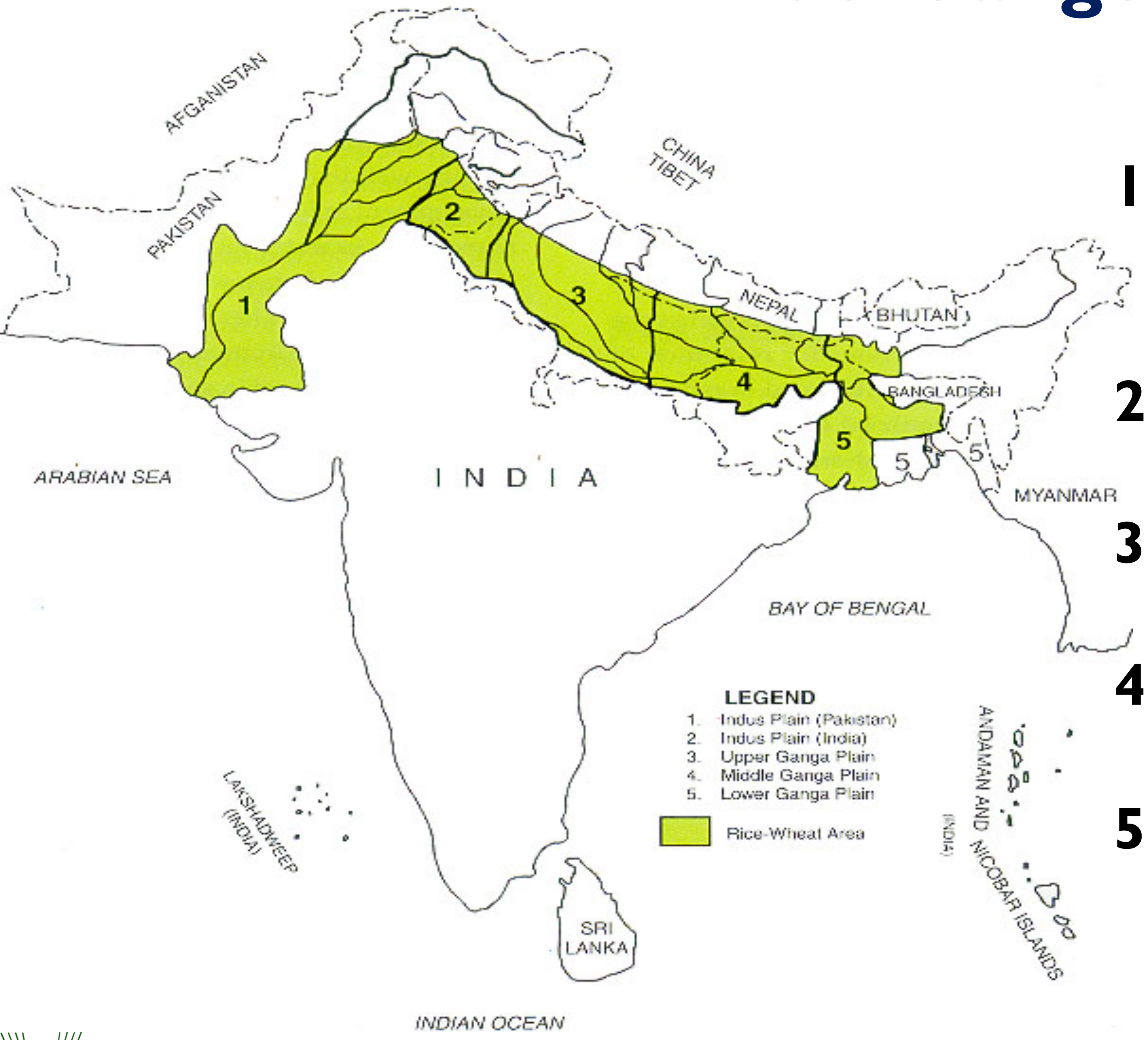
Global Rice-Wheat Systems



1. Single largest cropping system on the Earth.
2. Occupies 24 Mha in Asia.
3. Covers 28% of rice and 35% of wheat area.
4. These 2 crops make up more than 70% of the people's diet in Asia.
5. Crucial for achieving SDGs and net zero emission targets.

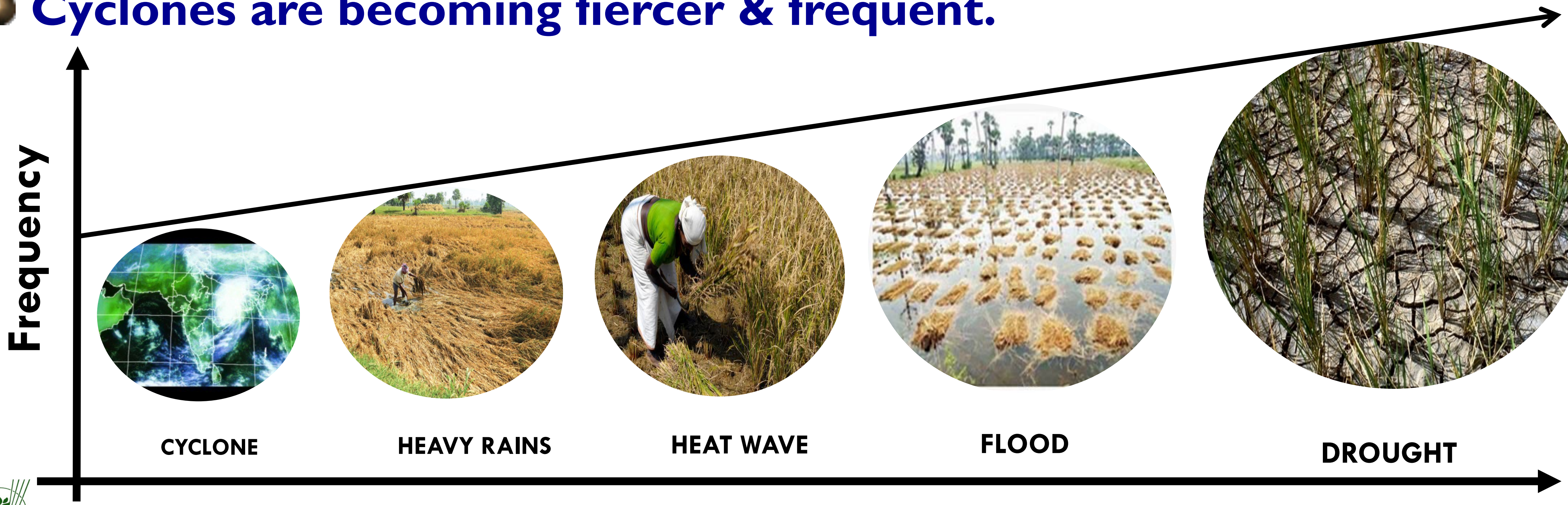
Indo-Gangetic Plains



1. **Occupy 1/6th of total geographical area of the sub-continent.**
2. **Hold ~45% of total population.**
3. **Produce >45% of total food.**
4. **Hold ~50% of total canal irrigation.**
5. **Consume ~30% fertilizer.**

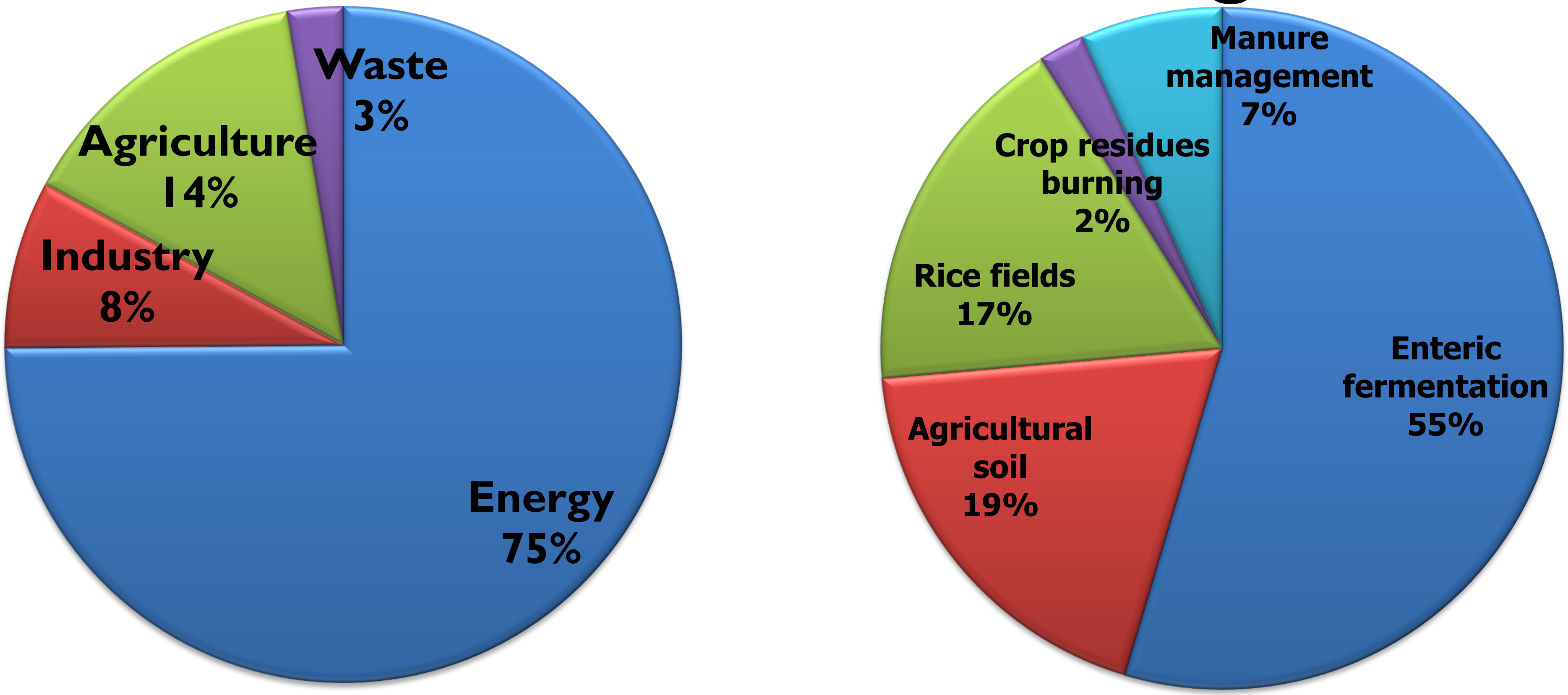
Climate Change is Aggravating

- **Global mean temperature increased by 1.1 ^{o}C.**
- **To increase by 3.5 ^{o}C by 2100. Last 6 years warmest.**
- **Seasons are shifting.**
- **Rainfall variability and intensity increasing.**
- **Sea level rising.**
- **Cyclones are becoming fiercer & frequent.**



IPCC (2021), Pathak et al. (2019)

Emission of GHGs from Indian Agriculture

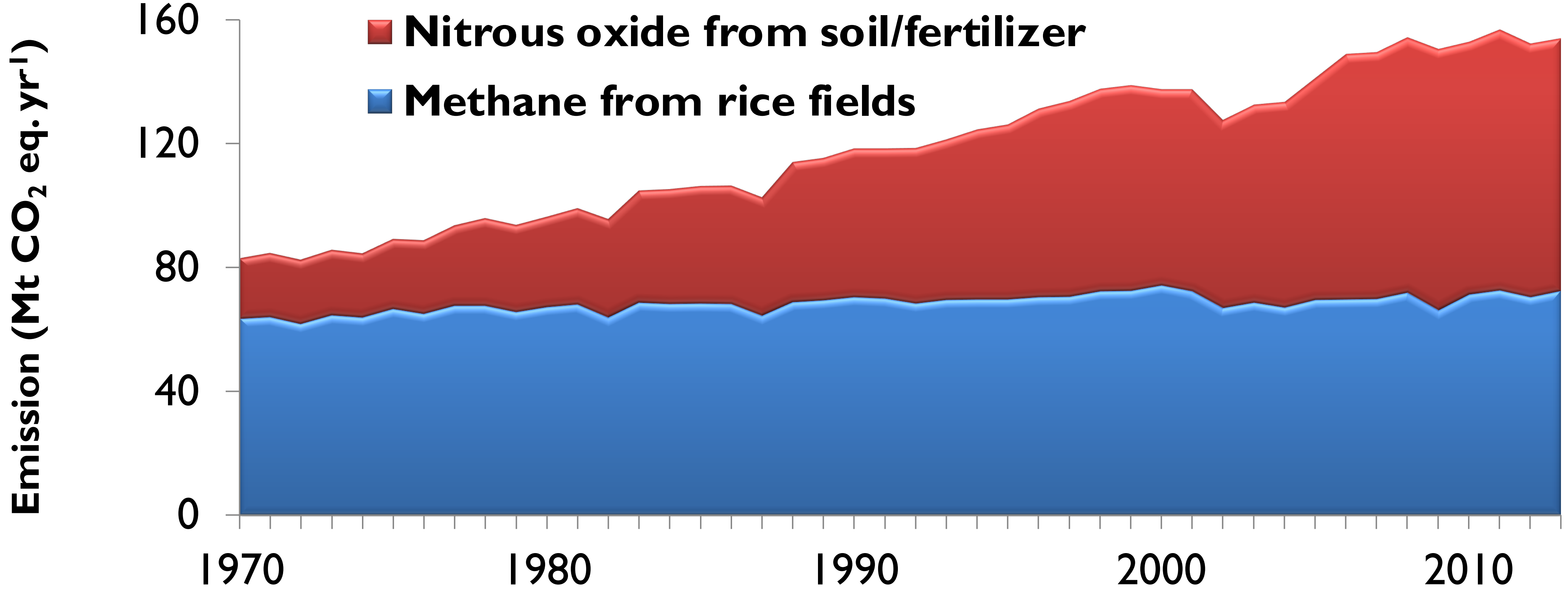


Different Economic Sectors | **Different Sub-sectors of Agriculture**

- **Total Emission: 2.82 Bt CO_2 eq.**
- **Emission from agriculture: 408 Mt CO_2 eq.**

MoEFCC (2020), Pathak et al. (2020)

GHGs Emissions from Indian Agriculture



- **Since 1970, the GHGs emission has doubled.**
- **Currently N_2O from soil and fertilizer is the largest source and increasing.**

Pathak et al. (2015)

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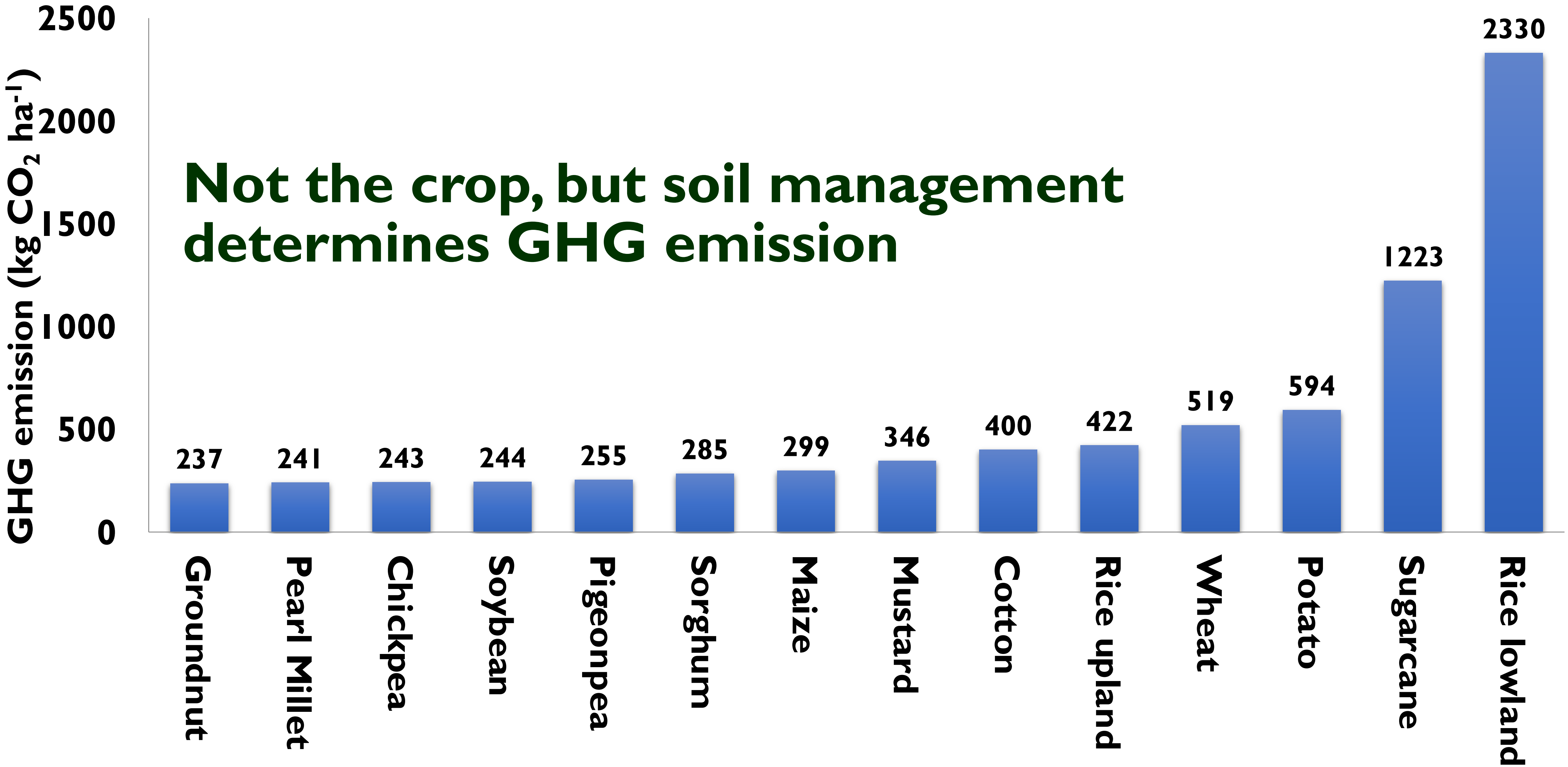
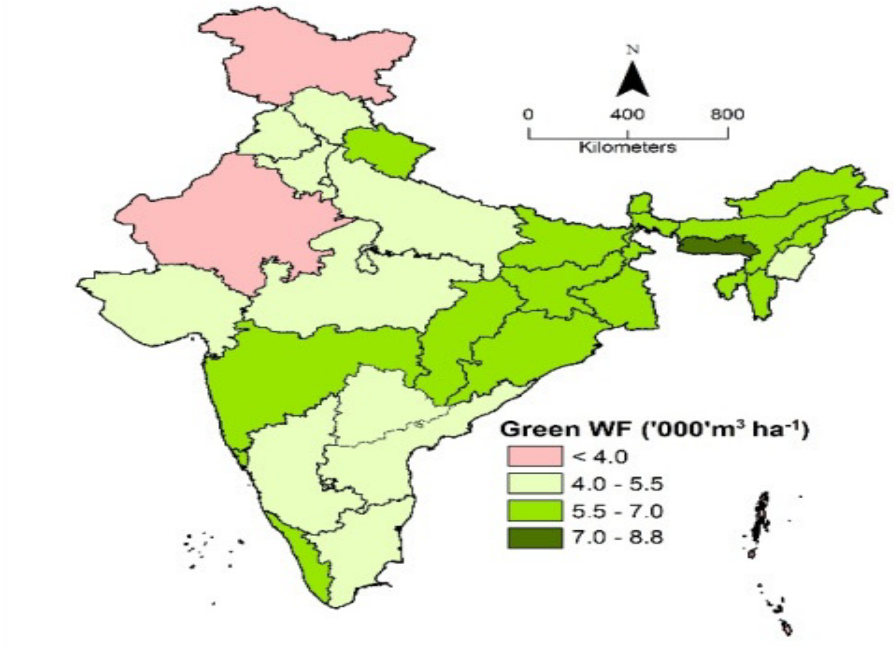
Greenhouse Gas Emission in Different Crops

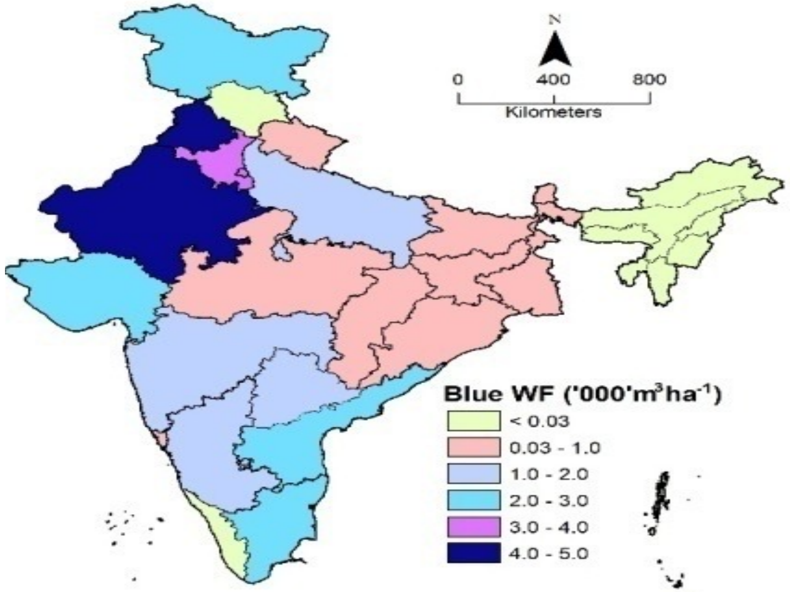


Pathak et al. (2015)

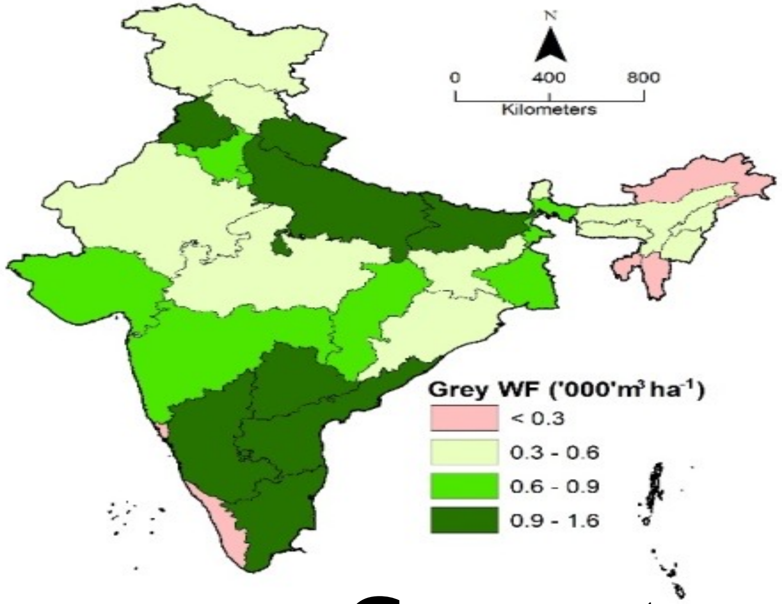
Large Water Footprints of Rice Production



Green water:
Rainwater and soil moisture



Blue water:
Irrigation water



Grey water:
Water to assimilate pollutant load

Rice receives 200 km^3 irrigation water per year (30% of total in India)

Nayak et al. (2018)

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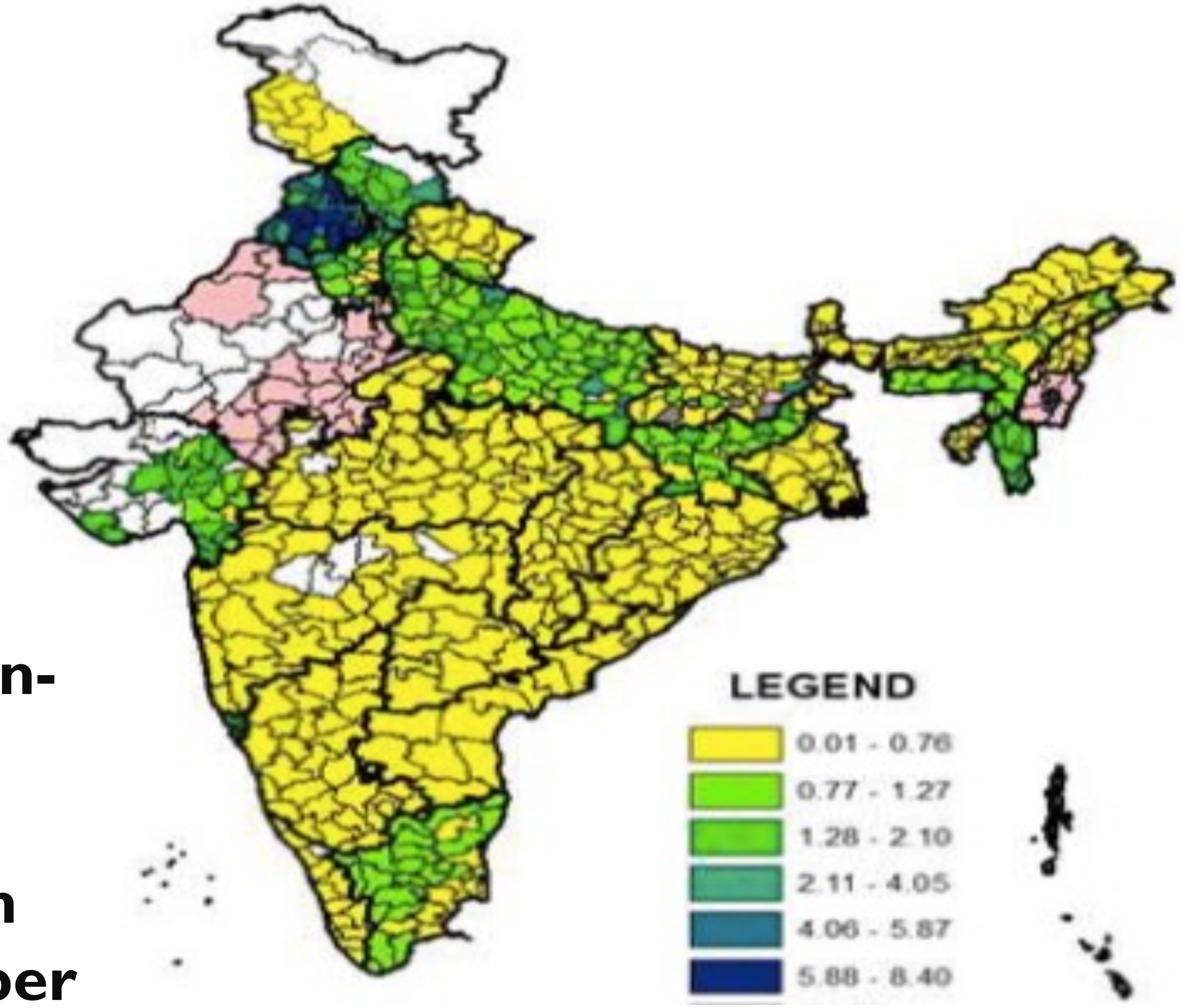
On-Farm Burning of Rice Stubble

- About 60 Mt of rice residues are burned on-farm.

- Economic cost of exposure to air pollution from stubble burning is Rs. 2 lakh crores per year in Punjab, Haryana and Delhi (IFPRI, 2019).



Rice Residue Surplus (t ha^{-1})

Jain, Pathak et al. (2018)

Impacts of Climate Change on Various Crops

Crop	Change in yield (%)
Wheat	-9
Irrigated rice	-12
Maize (kharif)	-18
Mustard	-12
Potato	-13
Sorghum	-3
Maize (rabi)	13

1. **Yields of wheat and rice would decline by 9 an 12% by 2040 under RCP 4. 5 scenario.**
2. **Suitability for rainfed rice area to decline by 15-40% by 2050.**
3. **Grain protein to reduce by 1% in wheat.**
4. **Zn and Fe content in many crops to reduce.**

Aggarwal et al. (2021); Naresh Kumar et al. (2019; 2020)

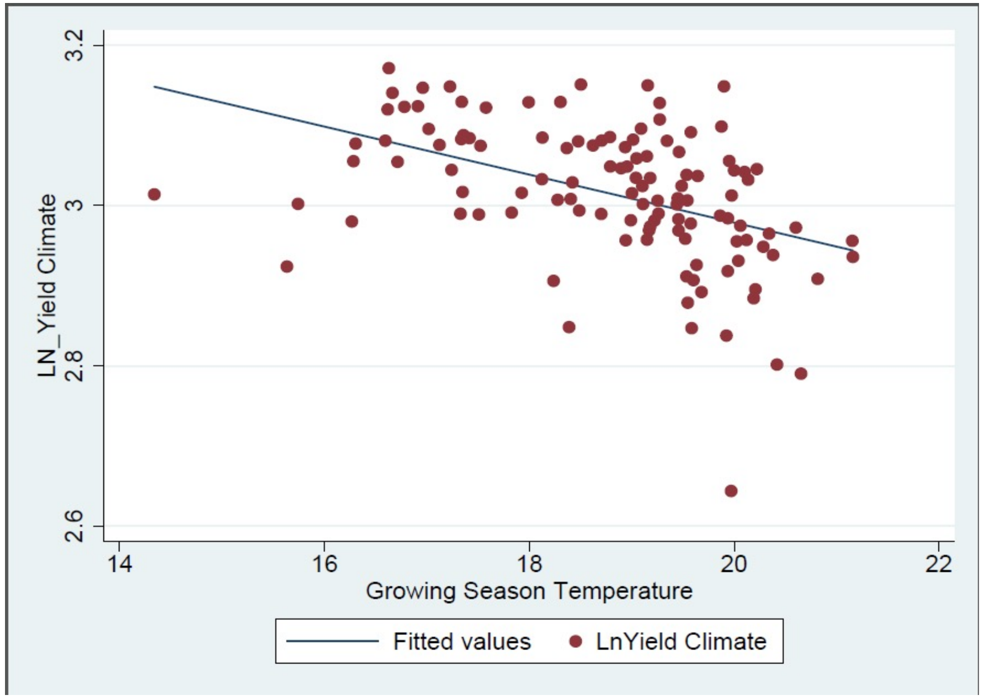
Impacts of Climate Change on Crop Productivity and Price

- **By 2030-40, nine out of ten major crops will experience reduced growth rate (8-23%) and increased prices (75-90%) due to climate change (CIMMYT 2015).**
- **IFPRI projects increased prices of wheat, rice and maize by ~150% by 2050 due to climate change.**

Contributions of Various Factors to Growth in Wheat Yield during the last 30 years (1981-83 to 2008-10).

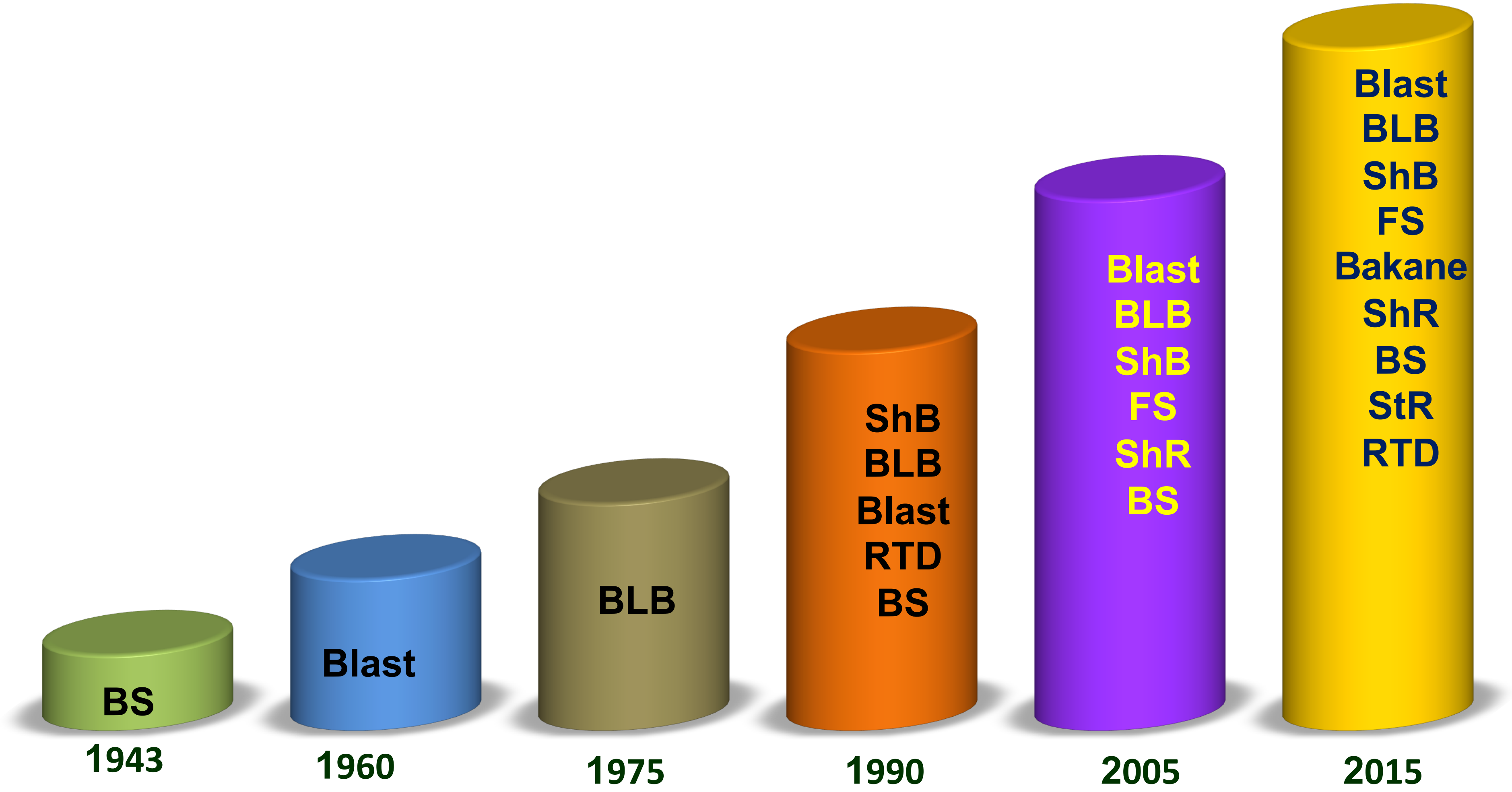
Variable	Change variable (%)	Contribution to growth (%)
1. Increased temp.	7.2	-10
2. Human labour	23.8	7
3. Machine labour	109.1	22
4. Fertilizer	98.3	50
5. Variety	-	31
Yield	**61.1**	**100**

Relation between temperature and wheat yield



Jha et al. (2019)

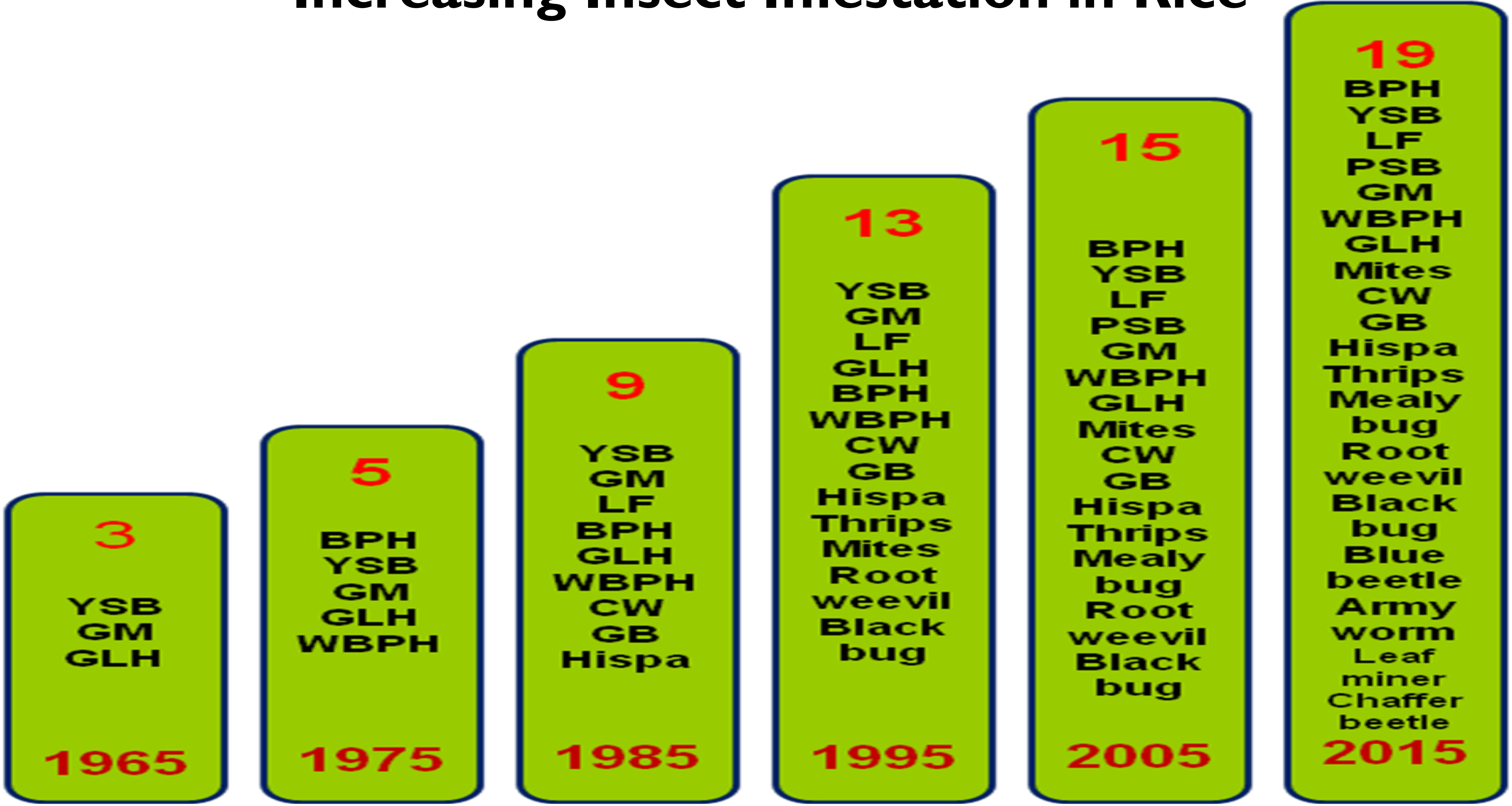
Increasing Disease Infestation in Rice



BS-Brown spot; BLB-Bacterial leaf bight; FS-False smut; GD- Grain discoloration; RTD-Rice tungro disease; ShB- Sheath blight; ShR-Sheath rot; StR-stem rot

Laha et al. (2016)

Increasing Insect Infestation in Rice



Laha et al. (2016)

Steps of Managing Climatic Risks

1. **F**oresee the stress (Forecasting)
2. **A**dapt the stress (Adapting)
3. **R**espond to the stress (Responding)
4. **M**itigate the stress (Mitigating)
5. **B**uild capacity to manage the stress (Capacity building)

FARM-Building

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Climate-Smart Management Options in Rice-Wheat System

1. Smart variety (Abiotic stress tolerant)
2. Smart tillage (Conservation tillage)
3. Smart fertilization (Demand-driven, sensor-based)
4. Smart irrigation (Micro, sensor-based, solar)
5. Smart processing and recycling (residue recycling, solar energy)

SMART-VTFIP

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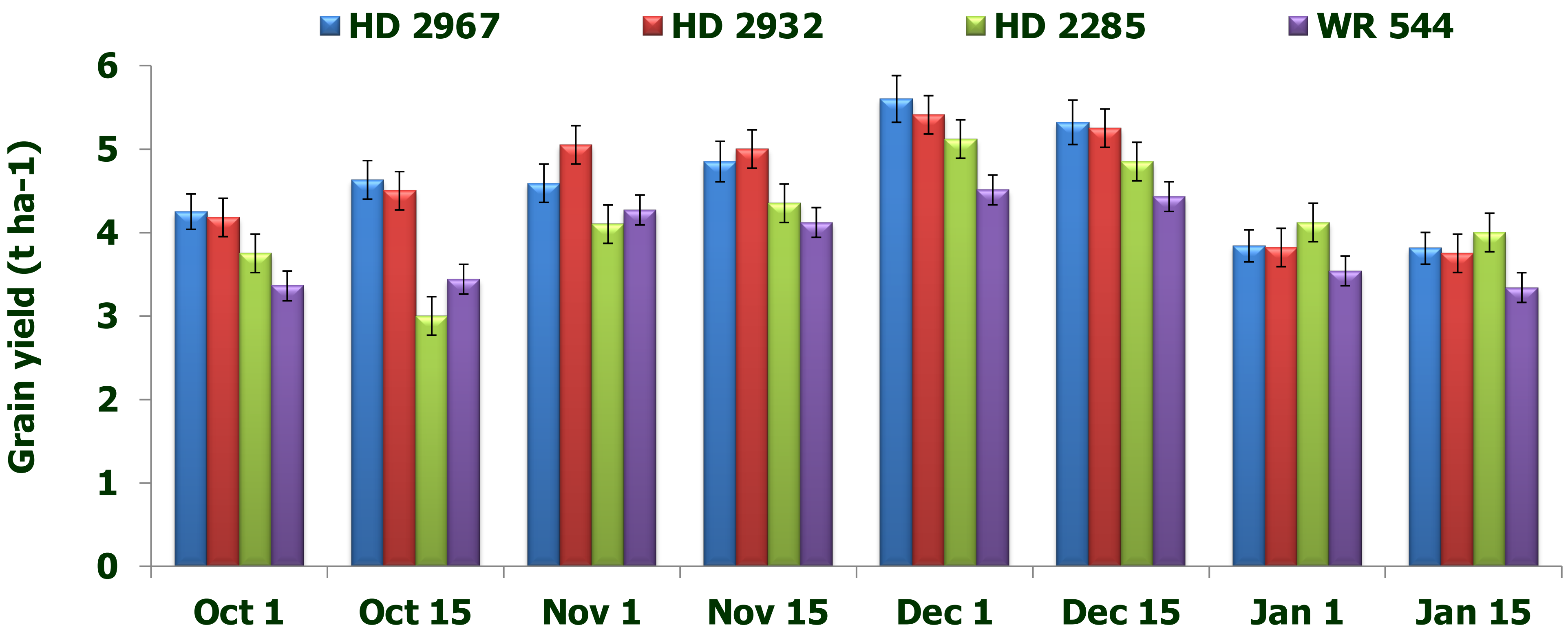
Climate-smart Crop Varieties

Varieties tolerant to:

- Submergence
- Drought
- Salinity
- Biotic stresses

Yield of Wheat Cultivars with Heat Stress



- Long duration cultivars (HD 2932 and HD 2967) gave higher yield under initial and terminal heat stress conditions.
- Medium duration cultivar (HD2285) gave higher yield under very late sown condition.

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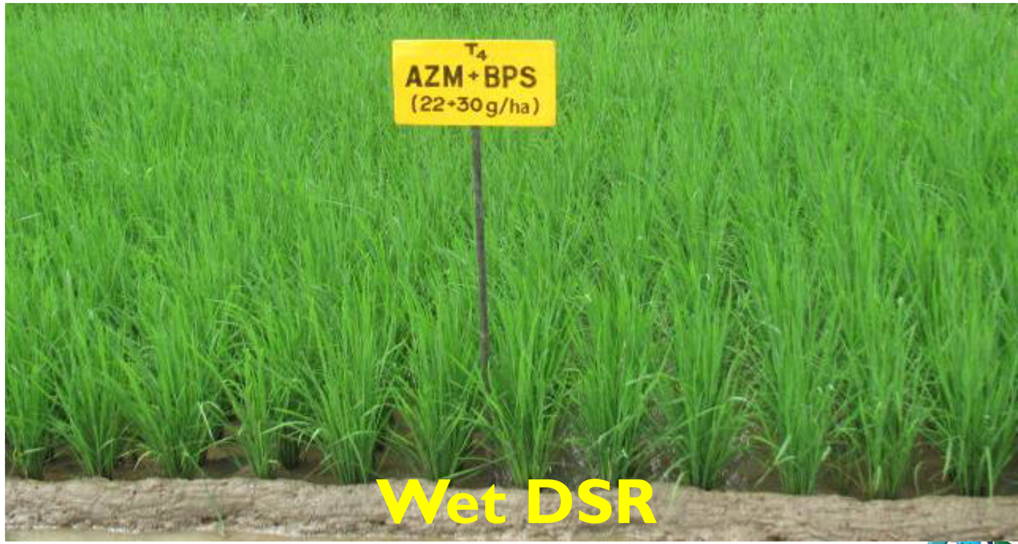
Advantages of Direct-seeded Rice

1. DSR saves resources
   1) Irrigation water — 25-30%
   2) Energy — 40-85%
   3) Labour — 25-30%
   4) Time (early maturity) — 8-10 days
2. Reduces GHG emission — 60-70%
3. Grain yield — 90-100%

DSR is a cost saving, labour saving, water saving, time saving, climate-smart rice farming



Observations from IARI, NRRI, CSSRI

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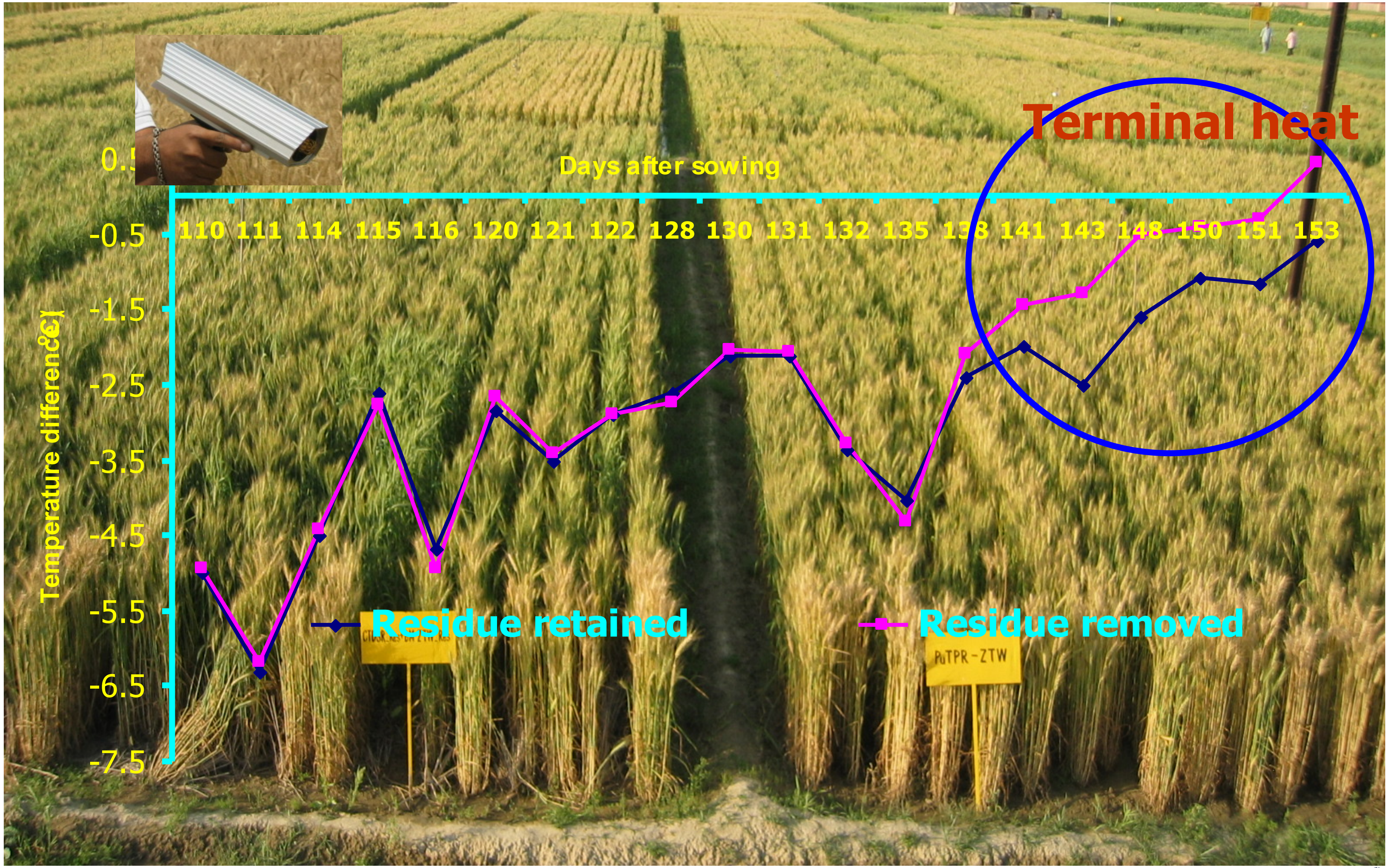
Conservation Agriculture Minimizes Yield Loss due to Climatic Extremes

Conventional

Conservation agriculture



NICRA (2016)

Jat et al. (2012)

Yield, Income, Water and Climate Benefits of Conservation Agriculture

Technology	Productivity gain (t ha^{-1})	Profitability gain (Rs. ha^{-1})	Water saving (%)	GHG mitigation (t CO_2 eq. ha^{-1})
1. Laser land leveling	0.5	14000	15	0.5
2. Zero till	0.4	9450	5	1.3
3. ZT + Residue	0.5	13300	8	1.8
4. DSR	0.0	9450	15	1.6
5. Permanent bed	0.8	21000	25	0.9
6. SSNM	0.5	13300	0	0.8
7. Sub-surface drip	0.4	12950	45	1.0
8. Crop diversification	0.7	24500	15	0.5
9. CSA package	1.0	15400	20	2.9

In conservation agriculture land preparation needs 80% less energy

Source: Jat et al. (2020), Pathak et al. (2021)

Productivity, Energy Use and GHG Emission in Punjab

System	Productivity (t/ha)	Energy use in ground water pumping (kWh)	GWP (kg CO2 eq. /ha)
Rice-wheat, flood irrigation	11.7	3702	3680
Rice-wheat, Drip + Solar	12.1	3723	0
Maize-wheat, flood irrigation	12.4	1181	1174
Maize-wheat, Drip + Solar	12.9	1189	0

Rolaniya et al. (2020)

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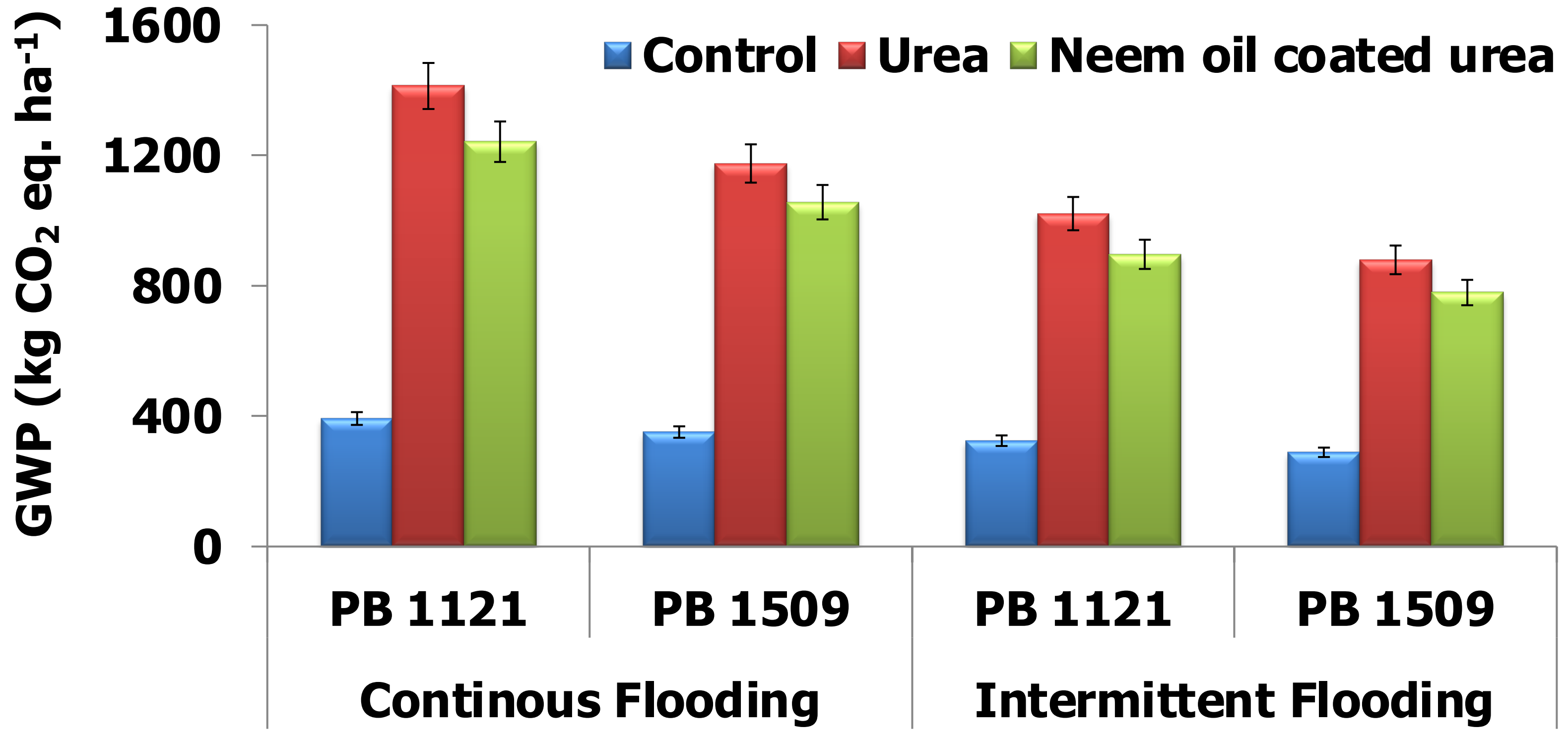
Greenhouse Gas Mitigation from Rice Fields

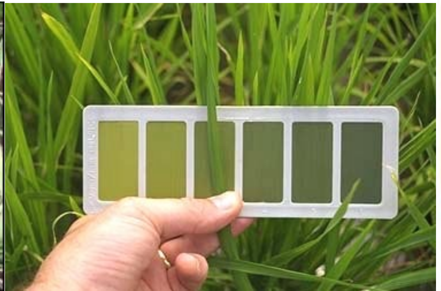


- **Intermittent flooding in rice reduced GWP by 25-30% over continuous flooding.**
- **Pusa Basmati 1509 reduced GWP by 15-20% compared to Pusa Basmati 1121.**
- **Neem coated urea decreased GWP by 10-12% compared to prilled urea.**

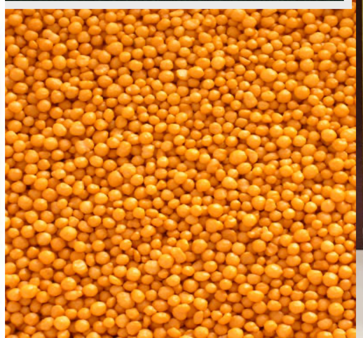
Pathak et al. (2015)

Improved Soil, Water and Nutrient Management

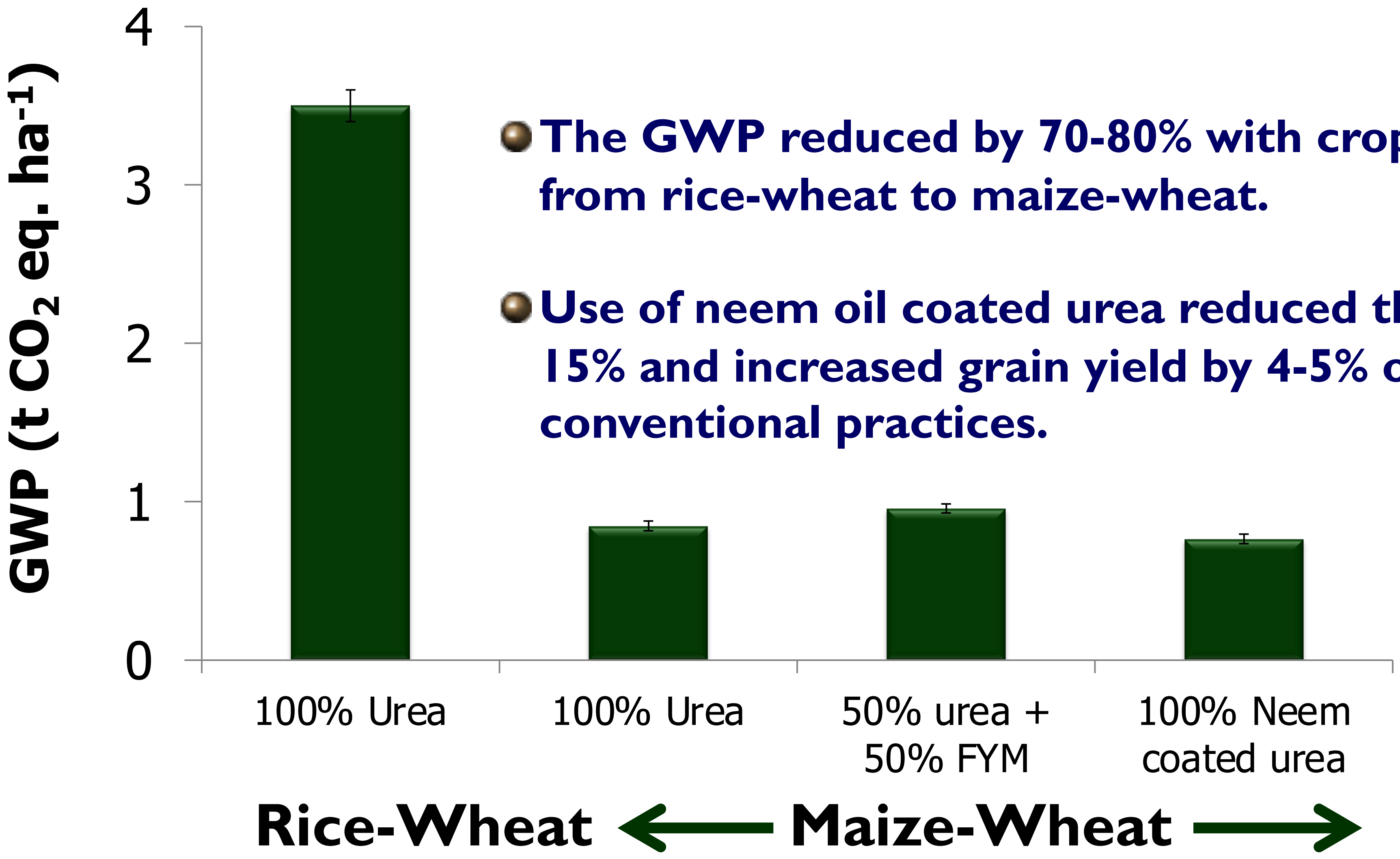
1. **Soil health card and site-specific nutrient management**
2. **Neem-coated urea**
3. **Leaf Colour Chart for N management**
4. **Microbial formulations nutrient supplementation**
5. **Integrated nutrient management**
6. **Efficient water management**
7. **Conservation agriculture**



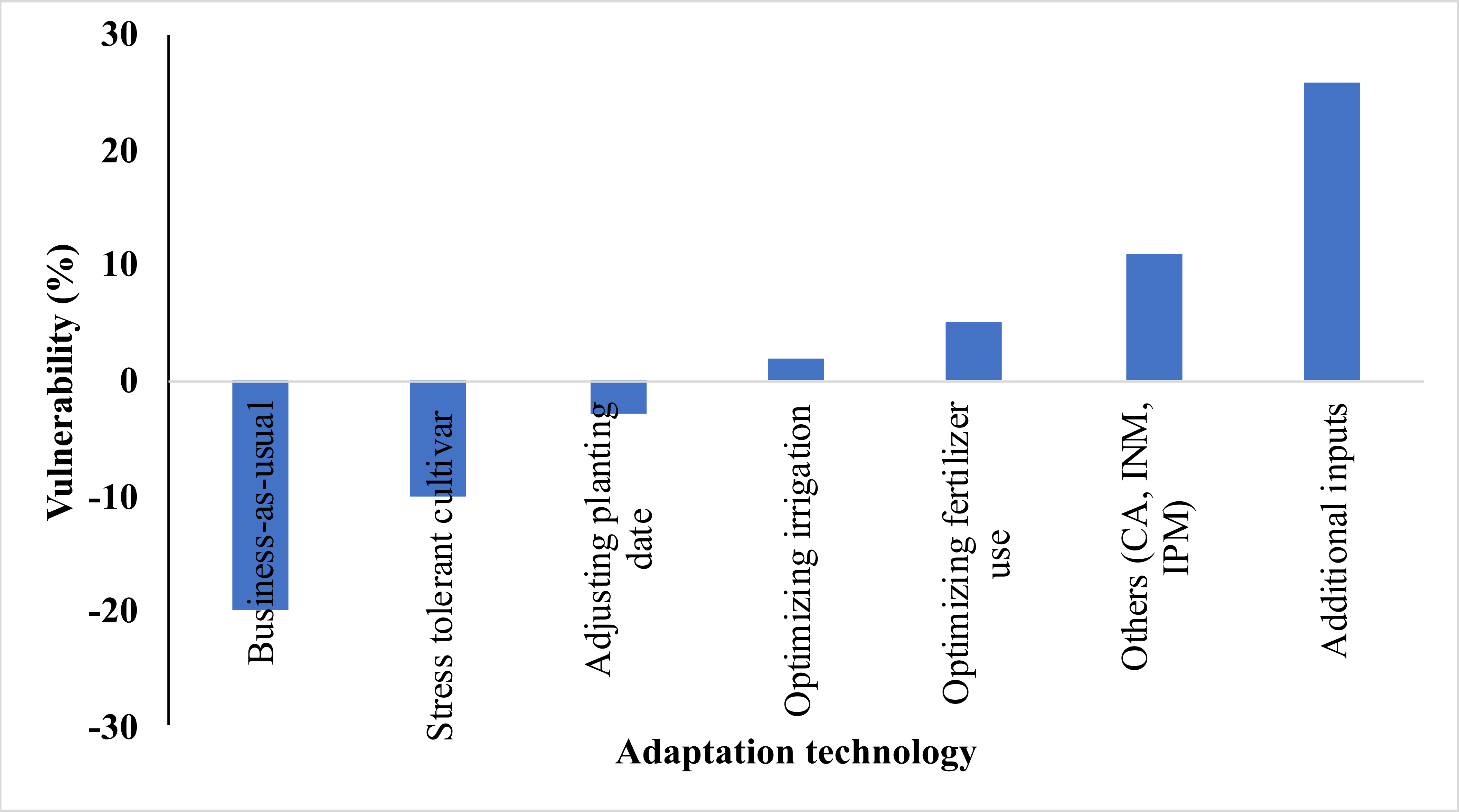



Mitigating GHG emission in rice-wheat system with crop diversification



- **The GWP reduced by 70-80% with crop diversification from rice-wheat to maize-wheat.**
- **Use of neem oil coated urea reduced the GWP by 10-15% and increased grain yield by 4-5% over the conventional practices.**

Adaptation technologies to compensate the vulnerability to climate change



Pathak (2022)

Technologies for GHGs Mitigation in Indian Agriculture: Potentials and Constraints

Technology	Mitigation (%)*	Yield (%)*	Constraints
Methane from rice field			
Intermittent drying	25-30	90-100	Assured irrigation
Direct-seeded rice	30-50	90-100	Machine, herbicide
Short duration variety	15-20	95-115	-
Nitrous oxide from soil			
Demand-driven N use	10-15	105-110	Knowledge, tool
Nitrification inhibitor	10-15	105-110	Cost, incentive
Carbon sequestration in soil			
Conservation agric.	5-10	95-110	Continuity
Integ. nutr. manage.	5-10	95-110	Manure avail., cost

*Compared to the conventional practices

Pathak et al. (2021)

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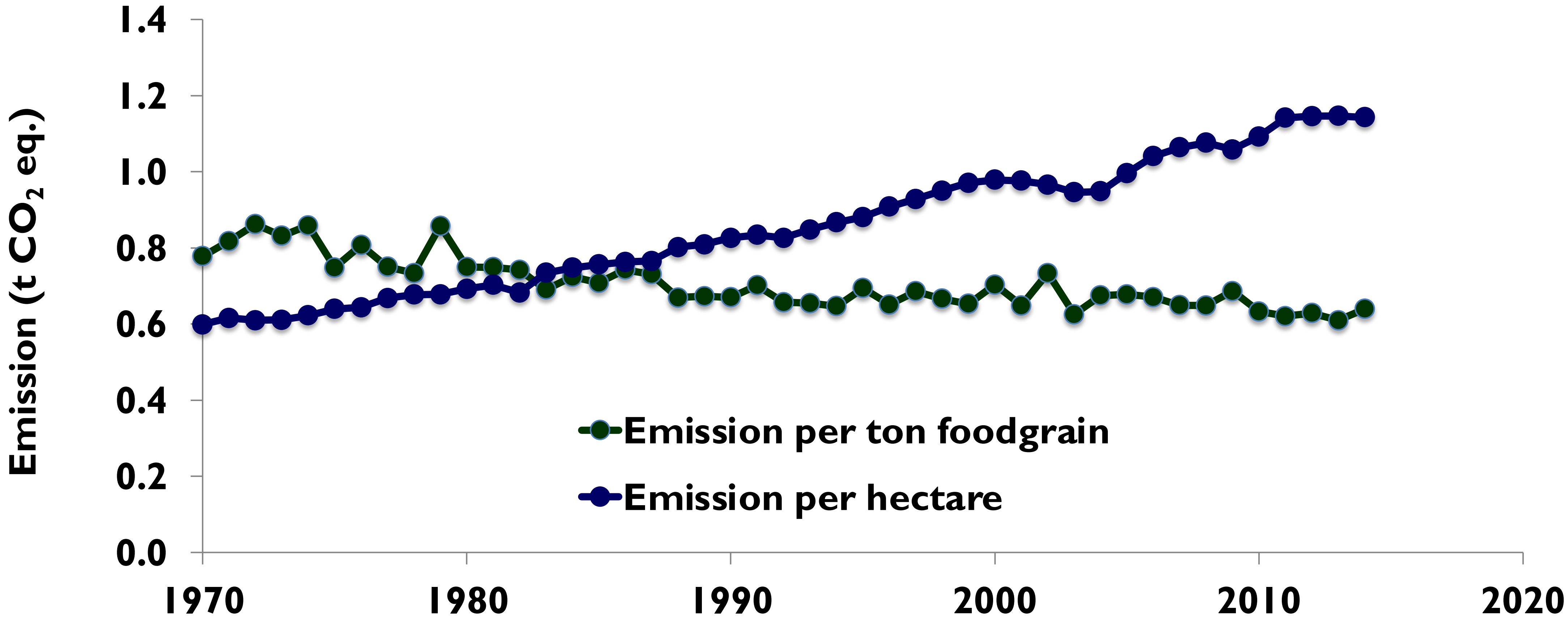
Trends in GHGs Emission from Indian Agriculture



Since 1970, GHGs emission per ha has almost doubled, but per ton food grain production decreased by 20%.

Pathak et al. (2018)

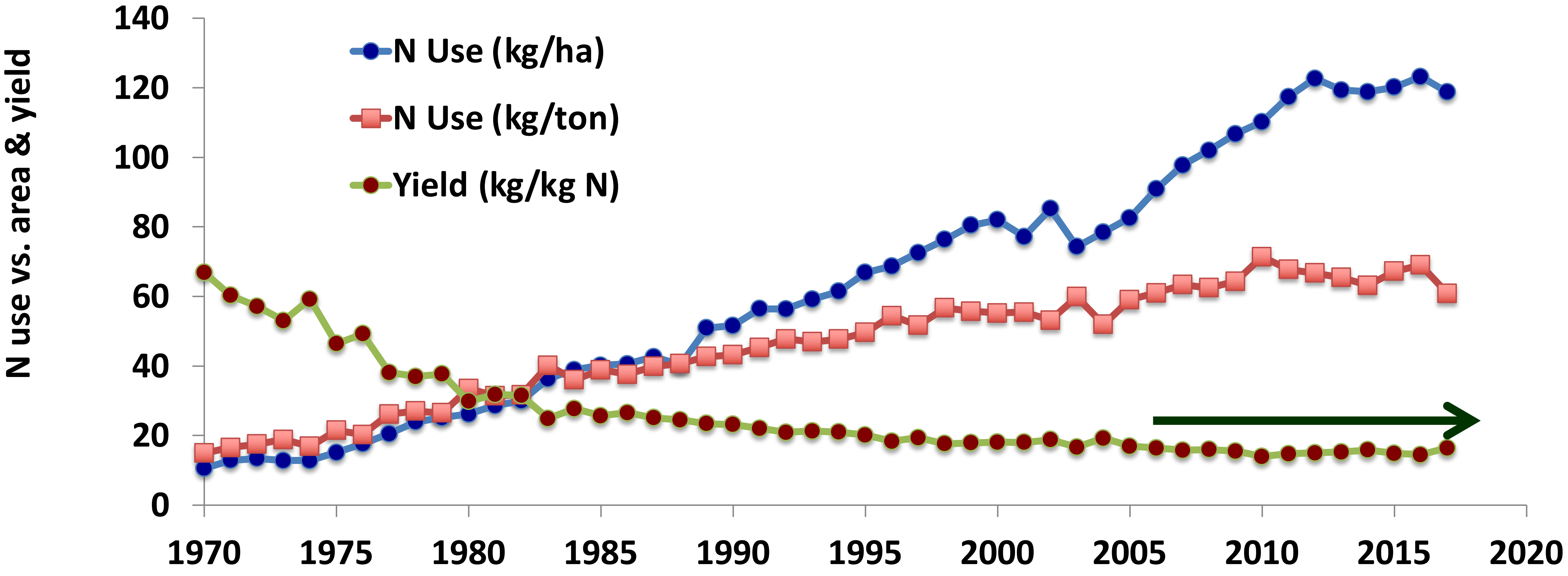
Impacts of Mitigation Technologies: Potential, Adoption and Mitigation

Greenhouse gas	Technology	Mitigation Potential (%)	Adoption (Mha)	Mitigation (Mt CO_2 eq)	Yield Impact (%)*
Methane	AWD	30	7.5	4.7	95
	DSR	40	4.0	3.4	90
	SRI	30	3.5	2.2	105
Nitrous oxide	LCC	15	40.0	1.9	110
	NCU	15	120.0	5.6	105
Carbon dioxide	RCT	10	3.5	0.7	105
	INM	10	25.0	5.0	110
Total/Average		**21**	**203.5**	**23.4**	**103**

- Total emission (Mt): 161.4
- Mitigation (Mt): 23.4
- Mitigation (%): 14.0

Pathak (2019)

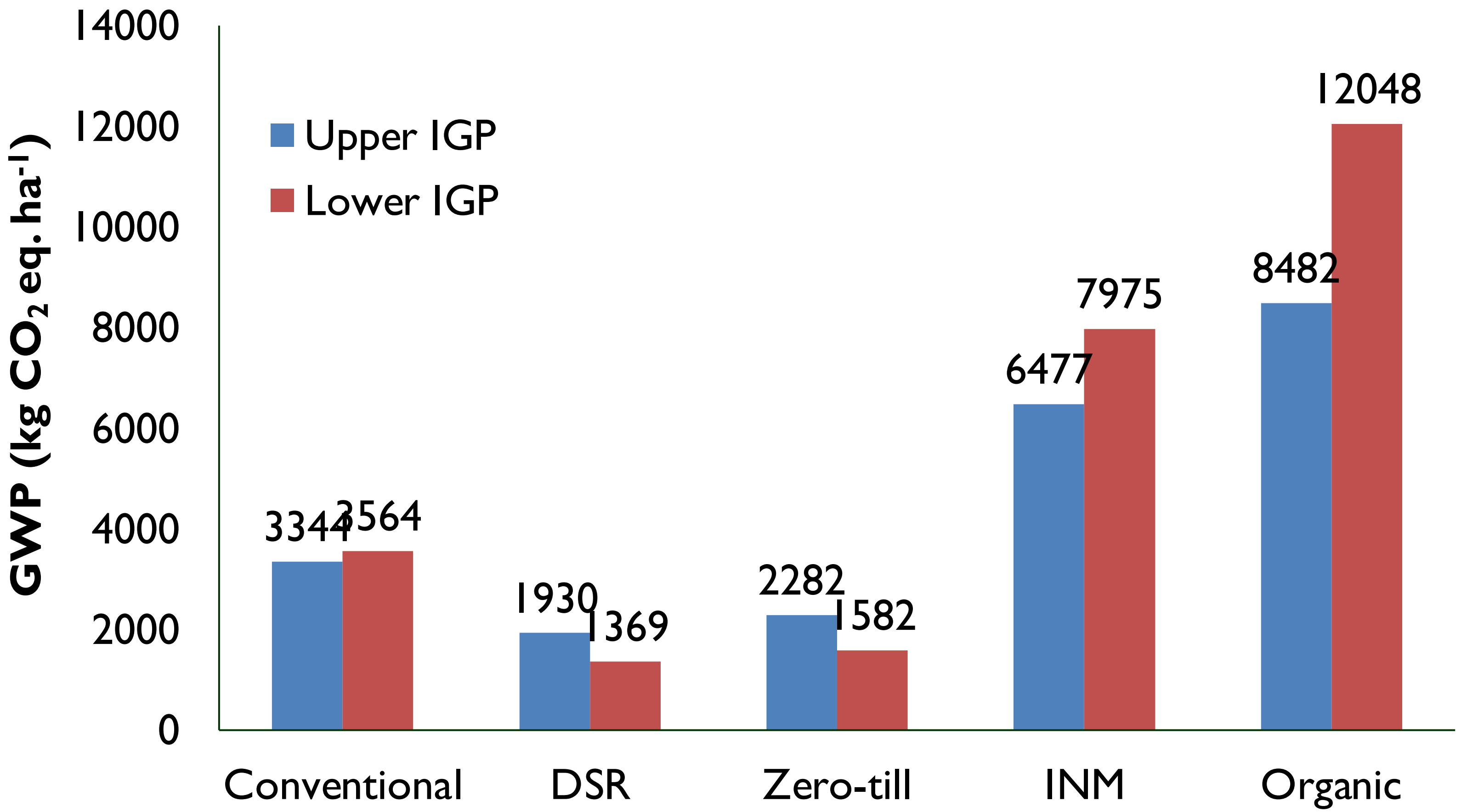
Trends in N Use in Relation to Area, Production and Productivity in Indian Agriculture



- Since 1970, N use per ha has increased by 11 times but per ton food grain production, it increased by 4 times.
- Since 1970, N response has decreased from 67 to 15 kg grain/kg N but since 1998, the response has remained 15-17 kg/kg N.

Pathak et al. (2018)

Global Warming Potential in Rice with Alternative Practices



Organic farming has higher GWP

Pathak et al. (2010)

Conservation agriculture should implemented completely

Happy seeder in wheat

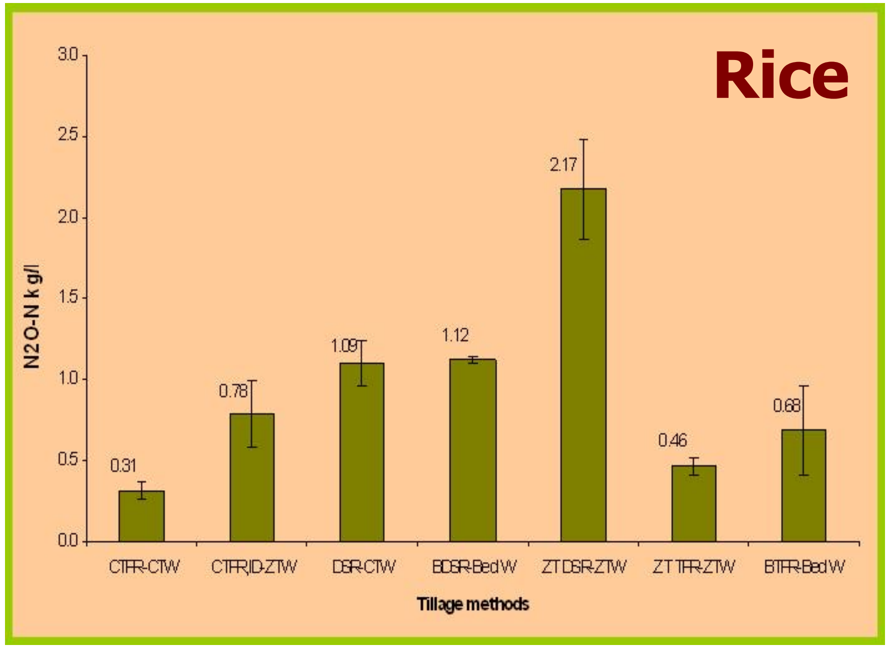
- No residue burning
- Zero tillage
- Less GHG emission
- But extra N? more N_2O

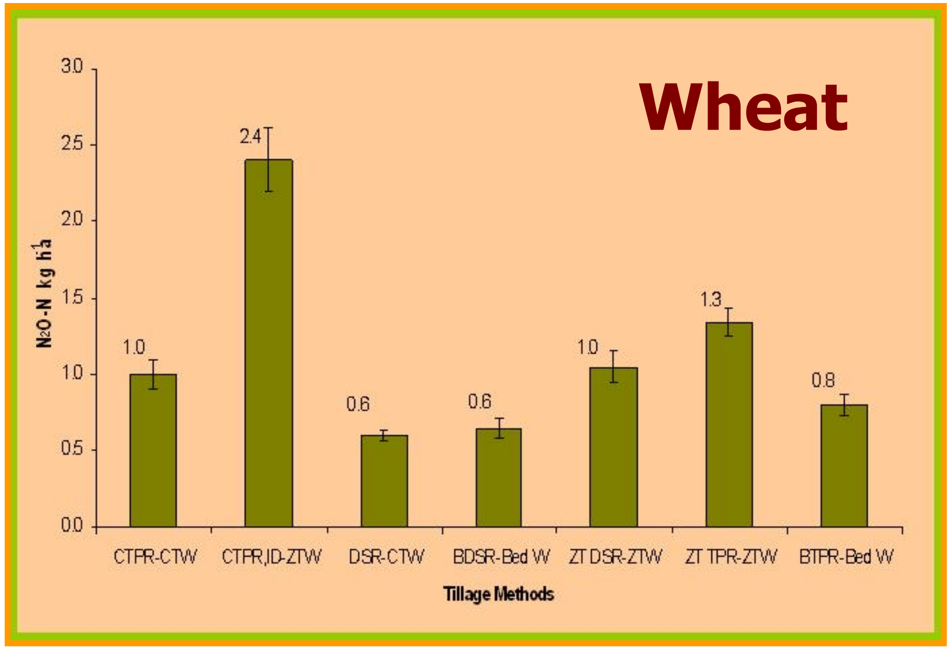
Puddling/submergence of C & N rich soil in rice

- More methane
- More nitrous oxide

Conservation agriculture should implemented rightly or continued

1. **Residue incorporation and puddling.**
2. **More water and N use in direct-seeded rice.**
3. **More N use in bed planted rice.**
4. **More N_2O emission in ZT-DSR.**
5. **Tillage after 3-4 years of ZT, losses the C gains.**





Mohanty et al. (2009)

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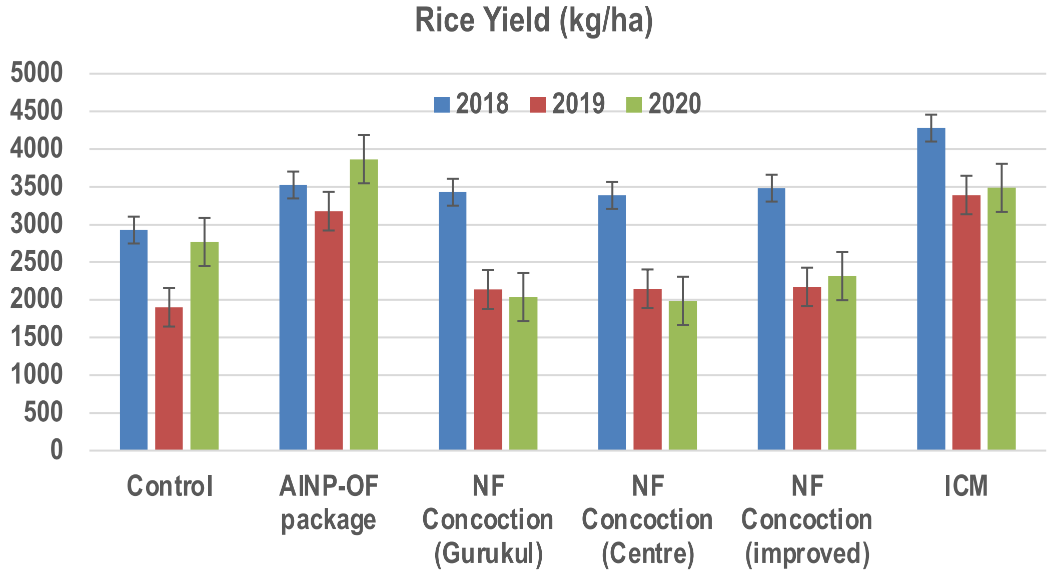
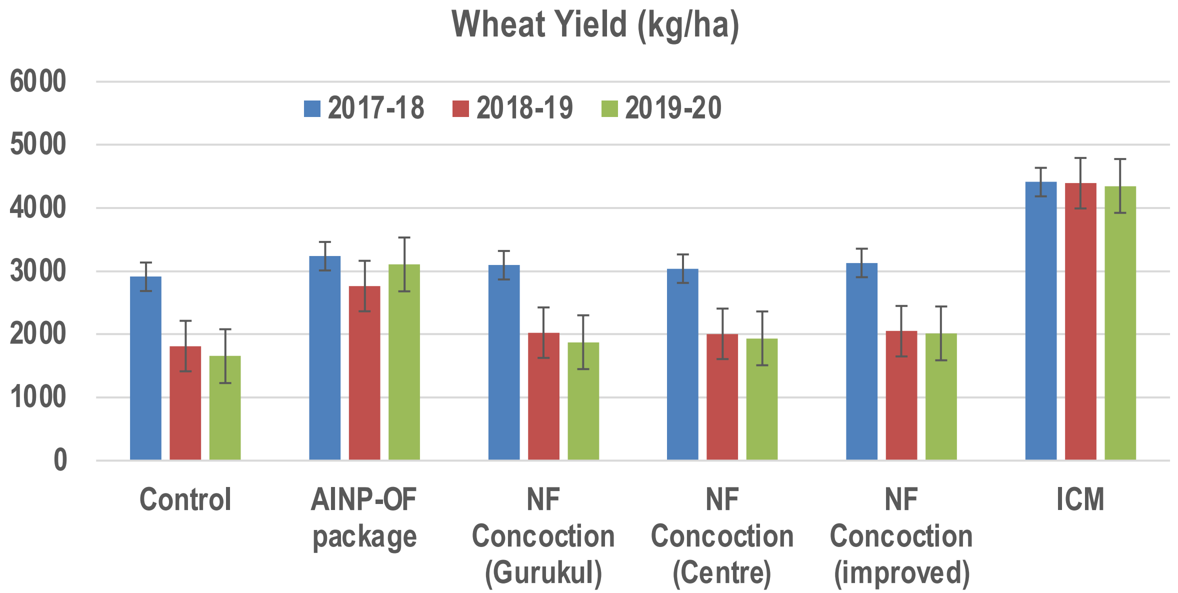
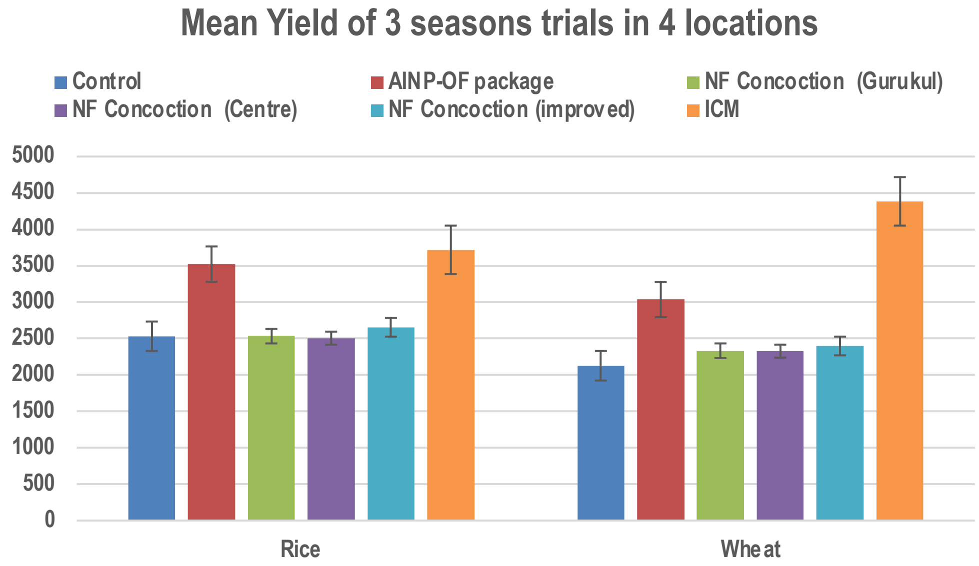
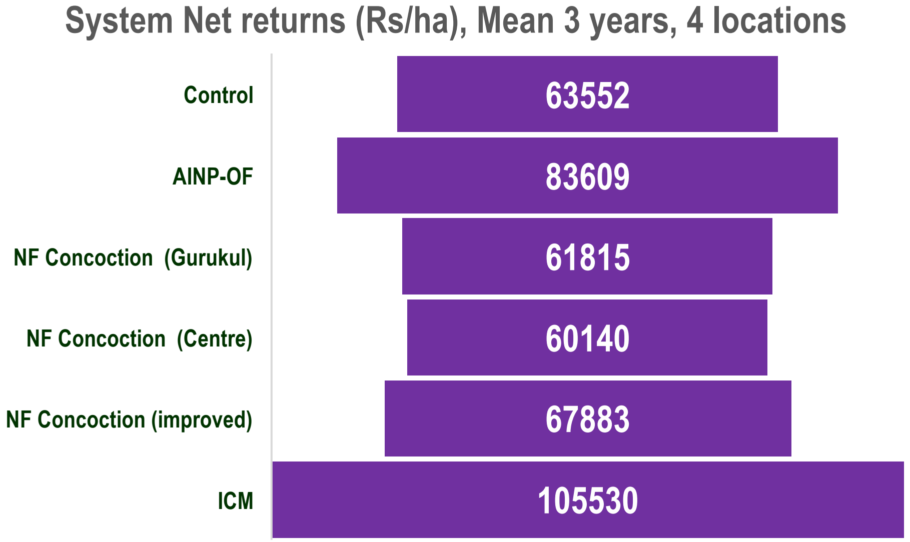
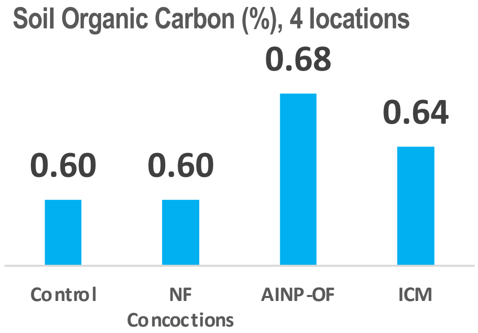
Organic, Natural and Integrated Farming in Rice-Wheat System (Kurukshetra, Ludhiana, Modipuram and Pantnagar)











Ravisankar (2022)

Way Forward

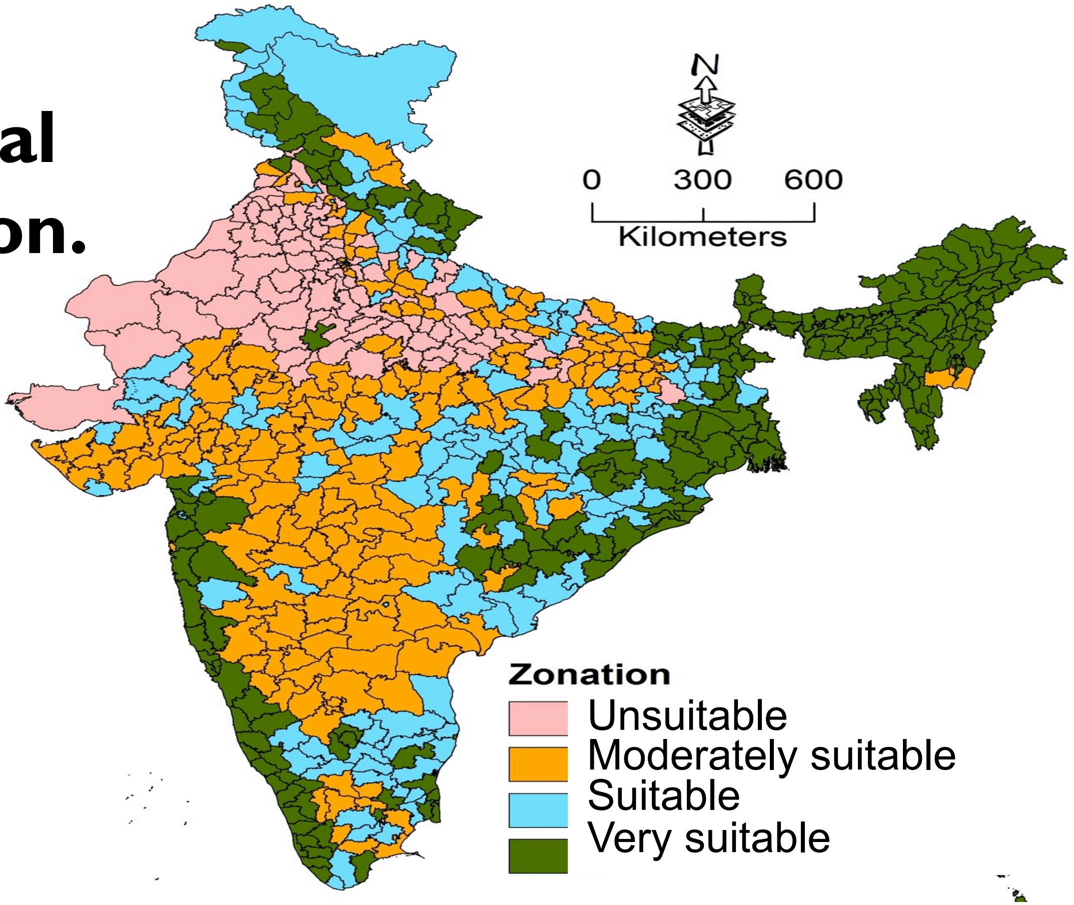
1

Eco-regional Crop Planning

- **Growing crop without degrading natural resources, with minimum GHG emission.**

- **Growing crop in suitable eco-regions:**

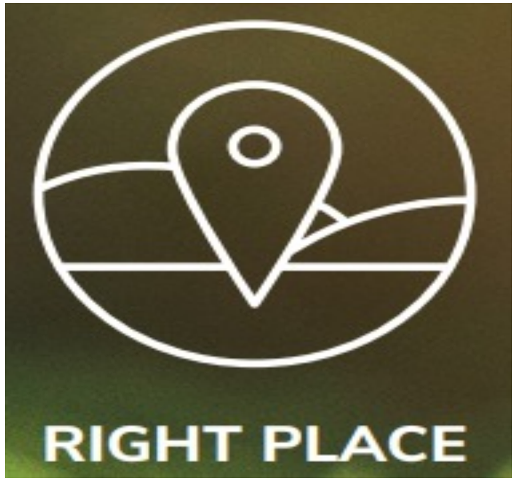
◆ Adequate rainfall: >1000 mm
◆ Fertile soil: Clay >25%
◆ Congenial temp.: Av. <27 °C



Suitable eco-regions for rice

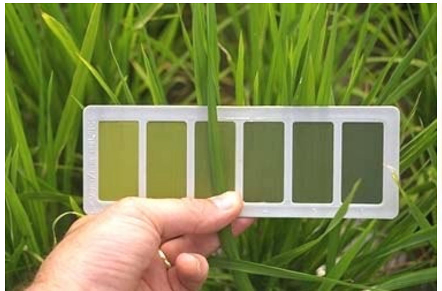
2

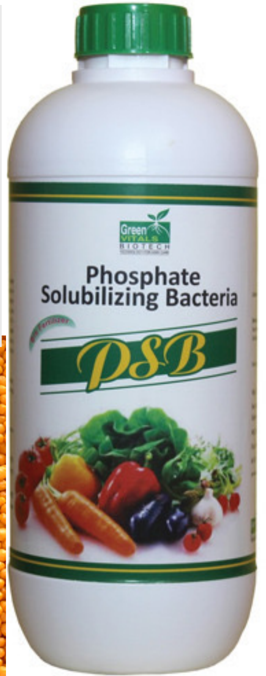
Judicious Use of Fertilizers using the 4R Approach



Balance the 4Rs

1. Neem-coated urea
2. Leaf colour chart
3. Urea deep placement
4. Soil health card
5. Nano-fertilizer





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3

Upscaling Resource Conserving Technologies (RCTs)

Conventional | **RCTs**

1. No-tillage


2. Laser land leveling


3. Direct seeding of rice


4. Micro-irrigation


5. Crop diversification


4 Use of Renewable Sources of Energy

1. Most farm machines are driven by fossil fuels, which contribute to GHG emissions.
2. Renewable resources such as solar, wind, biomass, tidal, geo-thermal, small-scale hydro, biofuels and wave-generated power can mitigate GHG emission.
3. This will minimize use of non-renewable resources, such as natural gas for fertilizer production or fossil fuel used in diesel generators for water pumping.
4. Solar photovoltaic water pumps and electricity, greenhouse technologies, solar dryers for post-harvest processing, and solar hot water heaters are economically viable and an climate-friendly options.

5

Policy for Climate-smart Agriculture

01
Market (Price, better rice, value addition, Seed, ICT)

02
Monsoon (Weather service, eco-regional planning)

03
Mechanization (Custom hiring service)

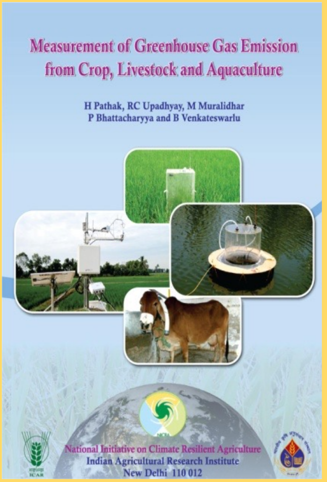
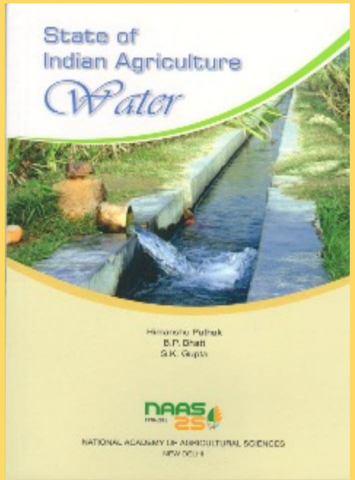
04
Management (Micro-irrigation, new fert. Manage, SRR)

05
Mainstreaming (Development, insurance, skill)

5 Ms for Climate-smart Agriculture

Conclusion

1. Climate change aggravates the problems of sustainability of rice-wheat system.
2. Rice-wheat system is the source and sufferer of climate change. But it can be a solution as well.
3. Climate-smart technologies are available. They need reorientation and upscaling.
4. Water, C and N budgeting should be integral parts of agricultural experiments and demonstrations.
5. Farmers'-friendly policy support is required to make it more resilient and diversified.


Measurement of Greenhouse Gas Emission from Crop, Livestock and Aquaculture
H Pathak, RC Upadhyay, M Muralidhar
P Bhattacharyya and B Venkateswarlu
National Initiative on Climate Resilient Agriculture
Indian Agricultural Research Institute
New Delhi 110 012

State of Indian Agriculture
Water
Himanshu Pathak
B.P. Bhatt
S.K. Gupta
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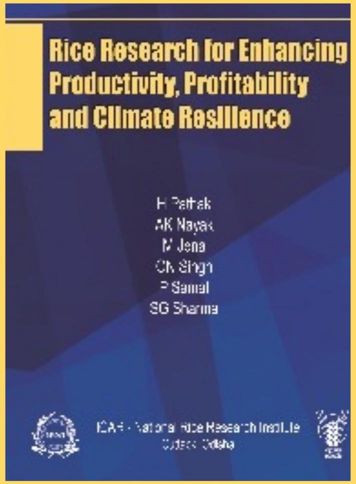
NEW DELHI

Rice Research for Enhancing Productivity, Profitability and Climate Resilience
H Pathak
AK Nayak
M Jena
ON Singh
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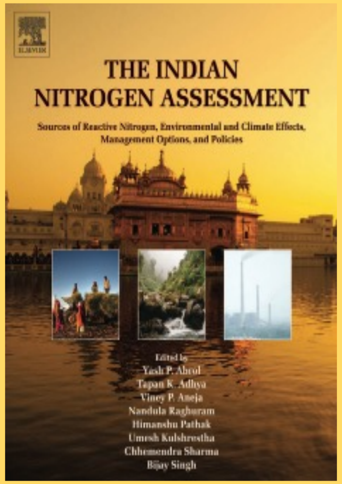
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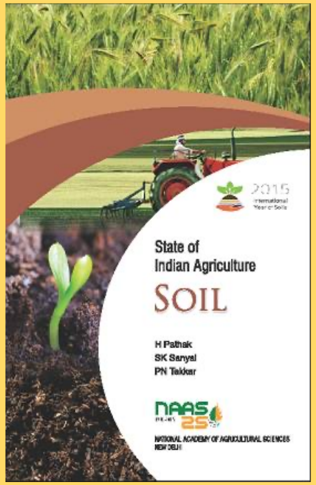
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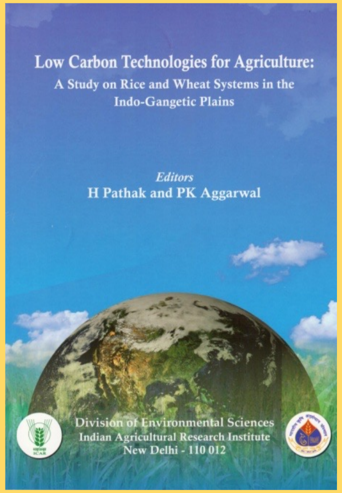
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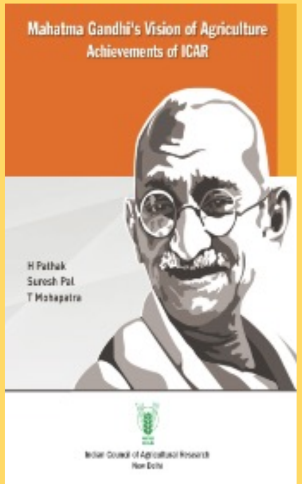
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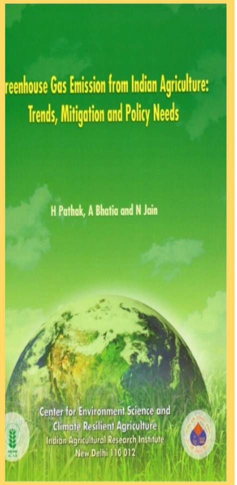
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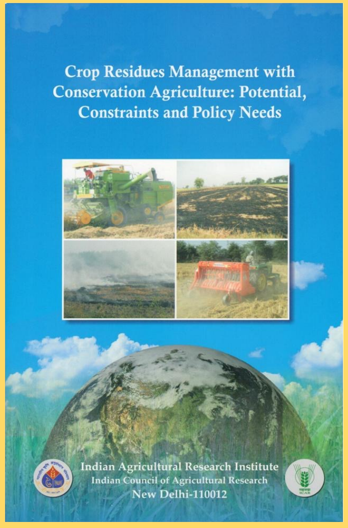
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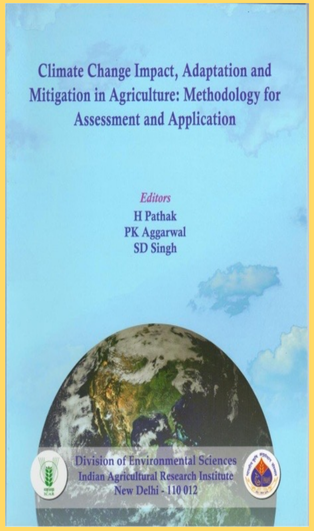
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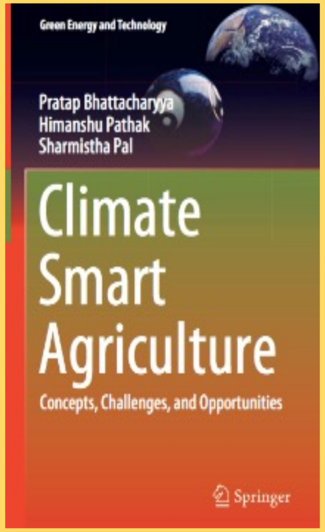
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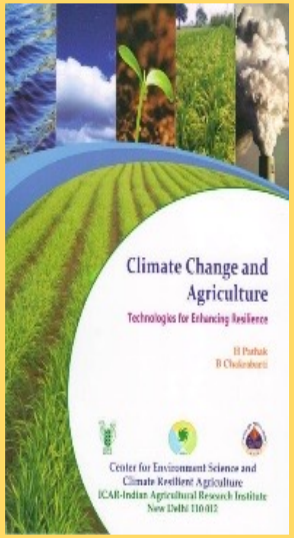
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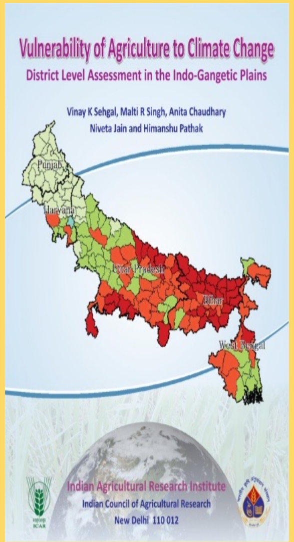
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