Conservation Agriculture based Sustainable Intensification for Challenging the Climate Change

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Climate Change Induced Extreme Weather Events in Recent Past

Year	SWM Rainfall Departure (%)
2000	-8
2001	-15
2002	-19
2003	+2
2004	-13
2005	-1
2006	-1
2007	+5
2008	-2
2009	-23
2010	+2
2011	+1
2012	-8

Extreme Events

- 2002 drought
- 20 day heat wave during May 2003 in Andhra Pradesh
- Extreme cold winter in the year 2002-03
- Drought like situation in India in July 2004
- Abnormal temperatures during March 2004 and Jan 2005
- Floods in 2005
- Cold wave 2005 - 06
- Floods in arid Rajasthan & AP and drought in NE regions in 2006
- Abnormal temperatures during 3rd week of Jan to 1st week of Feb 2007
- All India Severe drought 2009
- 2010 – One of warmest years
- 2011 – Failure of September rains in AP
- 2012 – Drought in Punjab, Haryana, Gujarat and Karnataka. Neelam cyclone, AP floods

Transitioning Towards Sustainability/Resilience

Need three non-linear stages in technology development (Pretty et al., 2018)

(i) *Efficiency*-focuses on making better use of resources within existing system configurations

(ii) *Substitution*- focus on replacement of technologies, practices etc

(iii) *Redesign* centers on composition and structure of agro-ecosystem involving social and institutional dimensions

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Science of scaling & enabling policy for impact at scale

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Conservation Agriculture (CA):

Provide opportunities for transitioning towards sustainability

The Theory of Change (ToC) for *'Transitioning Towards CA Mediated Sustainability and Resilience'*

- **Long-term process research- Science Evidence**
- **Participatory on-farm validation and refinement: backward and foreword integration**
- **Multi-disciplinary and multi-stakeholder (farmer centric) approach**
- **Science evidence backed policy informing**
- **Science of scaling: Business models and social inclusivity**
- **Capacity (Confidence) development**

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Efficiency

Eight Years of CA based Sustainable Intensification of Cereal Systems in NW India: Productivity, Profitability, Soil quality and Environmental footprints

Scenario	Productivity ($Mg\ ha^{-1}$)	Irrigation water ($mm\ ha^{-1}$)	Energy requirement ($MJ\ ha^{-1}$)	Net return ($USD\ ha^{-1}$)	Organic carbon (%)	Total GWP ($t\ CO_2\ eq\ ha^{-1}$)
Conventional RW	12.40	2557	75225	1361	0.45	6.3
CA based RW	13.17 (6)	1868 (-27)	57833 (-23)	1629 (20)	0.90 (100)	4.9 (-22)
CA based MW	14.09 (14)	738 (-71)	39376 (-48)	2122 (56)	0.84 (87)	4.5 (-29)

*In parenthesis= % change over conventional system

Source: ICAR-CSSRI-CIMMYT Collaborative Long-term Research platform

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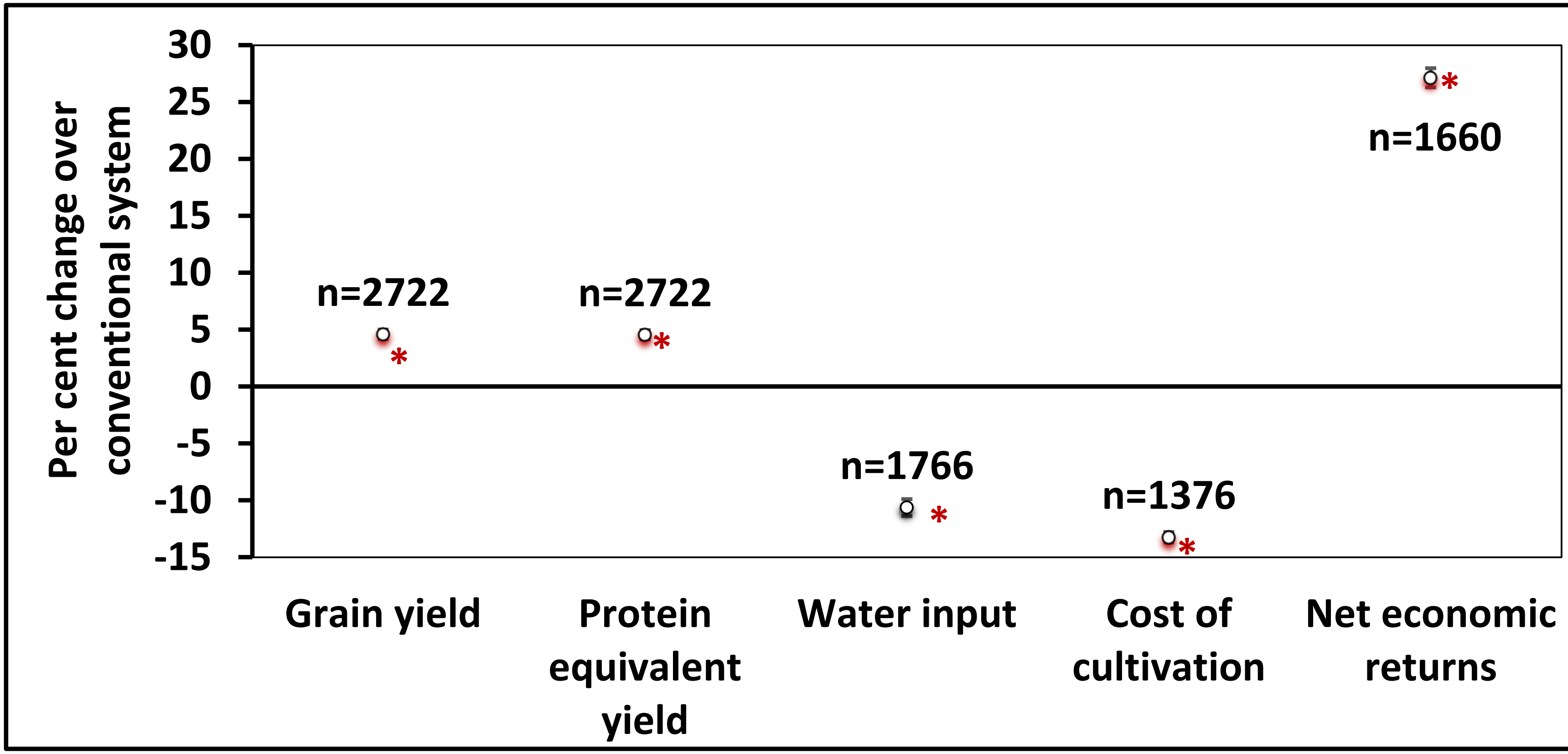
Meta analysis: Multi-criteria performance of CA in major cereal based systems in South Asia



Yield: 5, water: 10, Cost: 13, Income: 27

Jat et al (Forthcoming)

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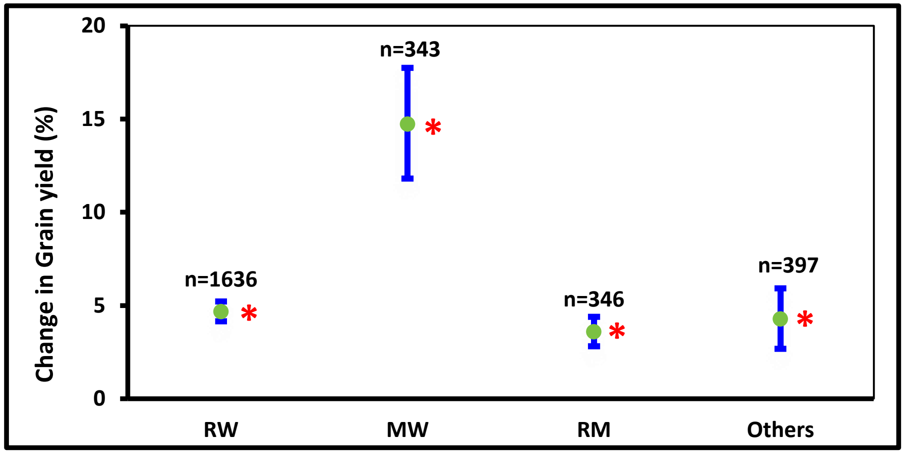
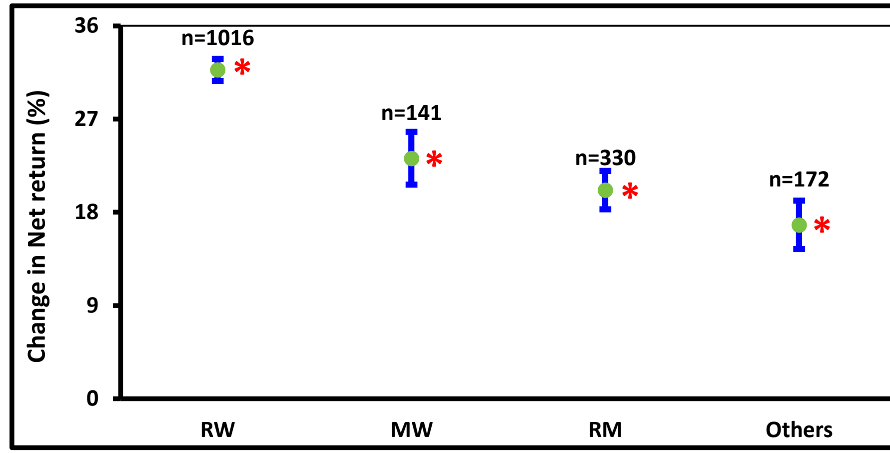
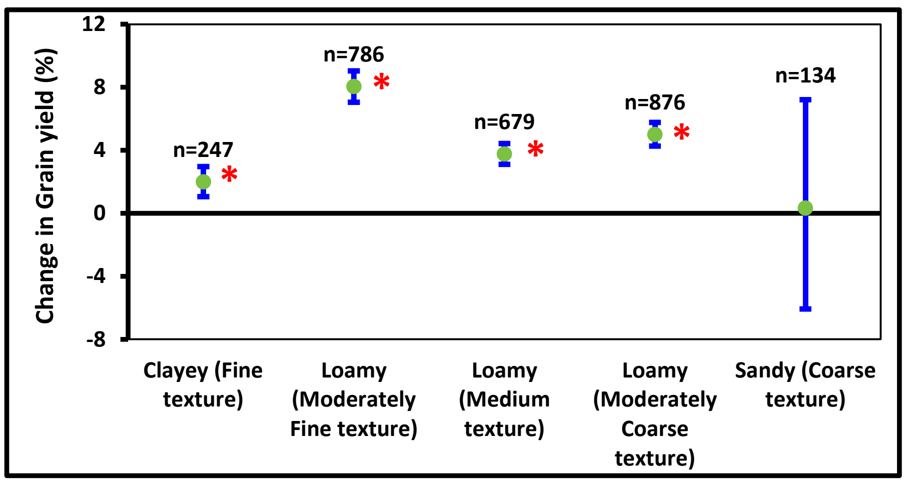
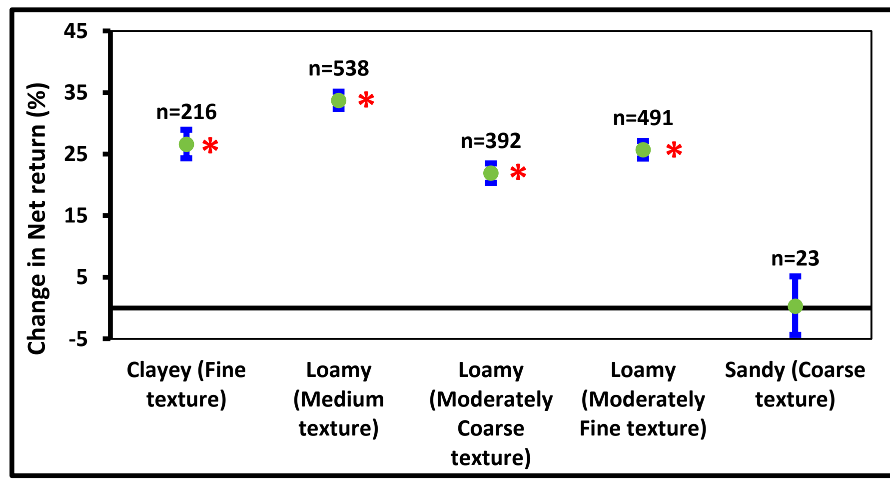
Meta analysis: performance (yield and income) of CA in different cropping systems and soil types









Jat et al (Forthcoming)

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Meta-Analysis: Alternate Rice Production Systems

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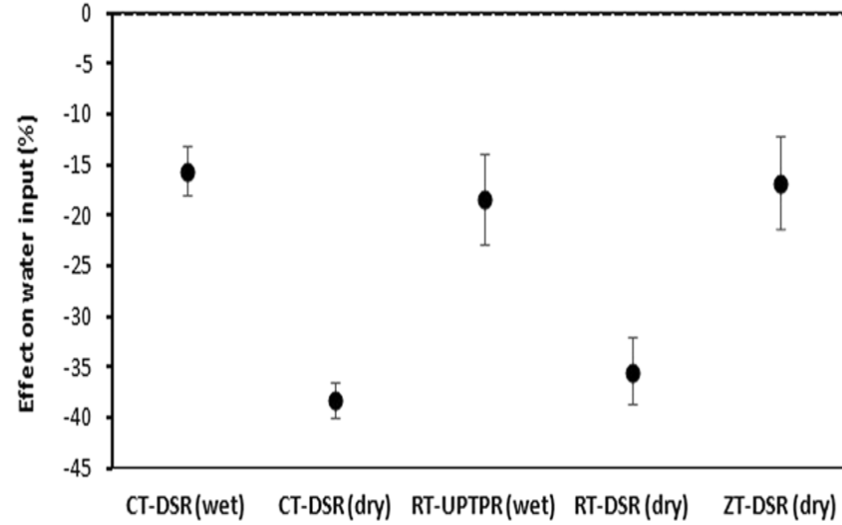
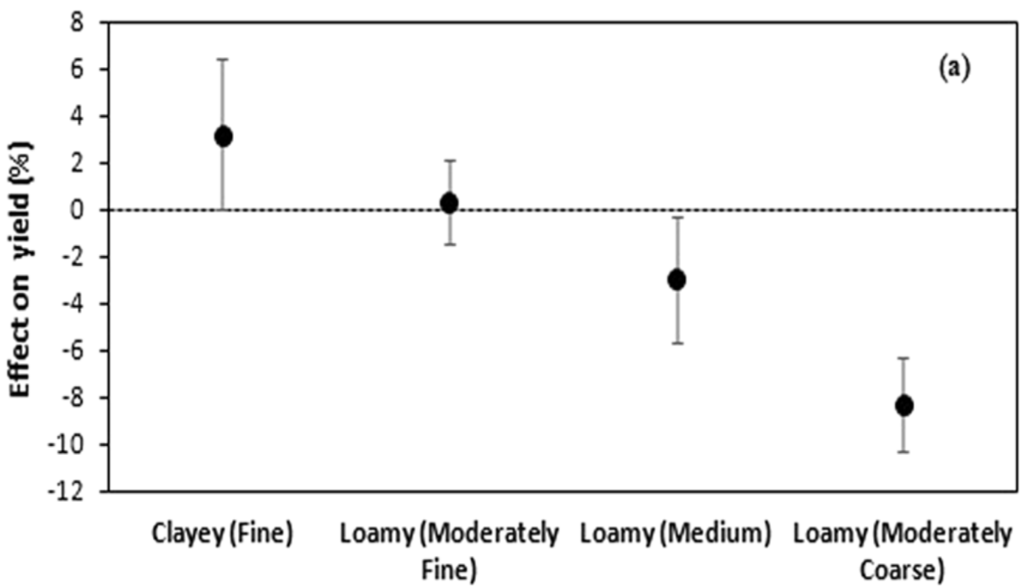
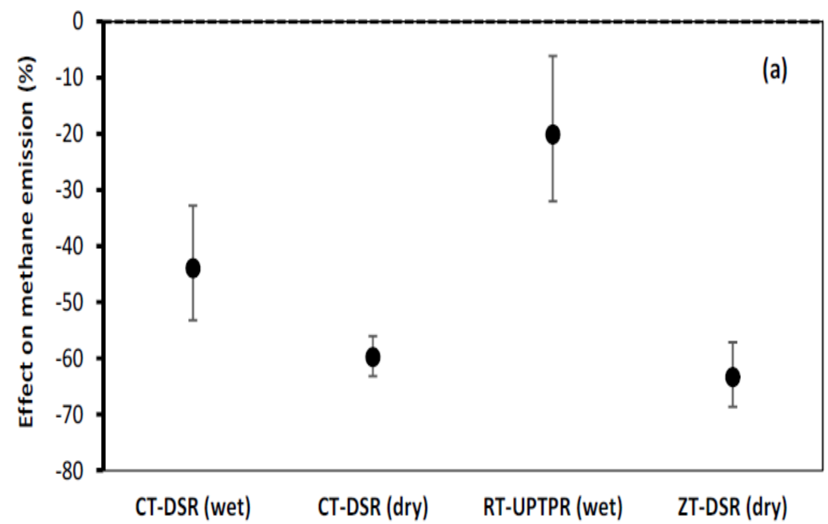
A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production

Debashis Chakraborty[1], Jagdish Kumar Ladha[2], Dharamvir Singh Rana[3], Mangi Lal Jat[4], Mahesh Kumar Gathala[5], Sudhir Yadav[2], Adusumilli Narayana Rao[6], Mugadoli S. Ramesha[2] & Anitha Raman[6]

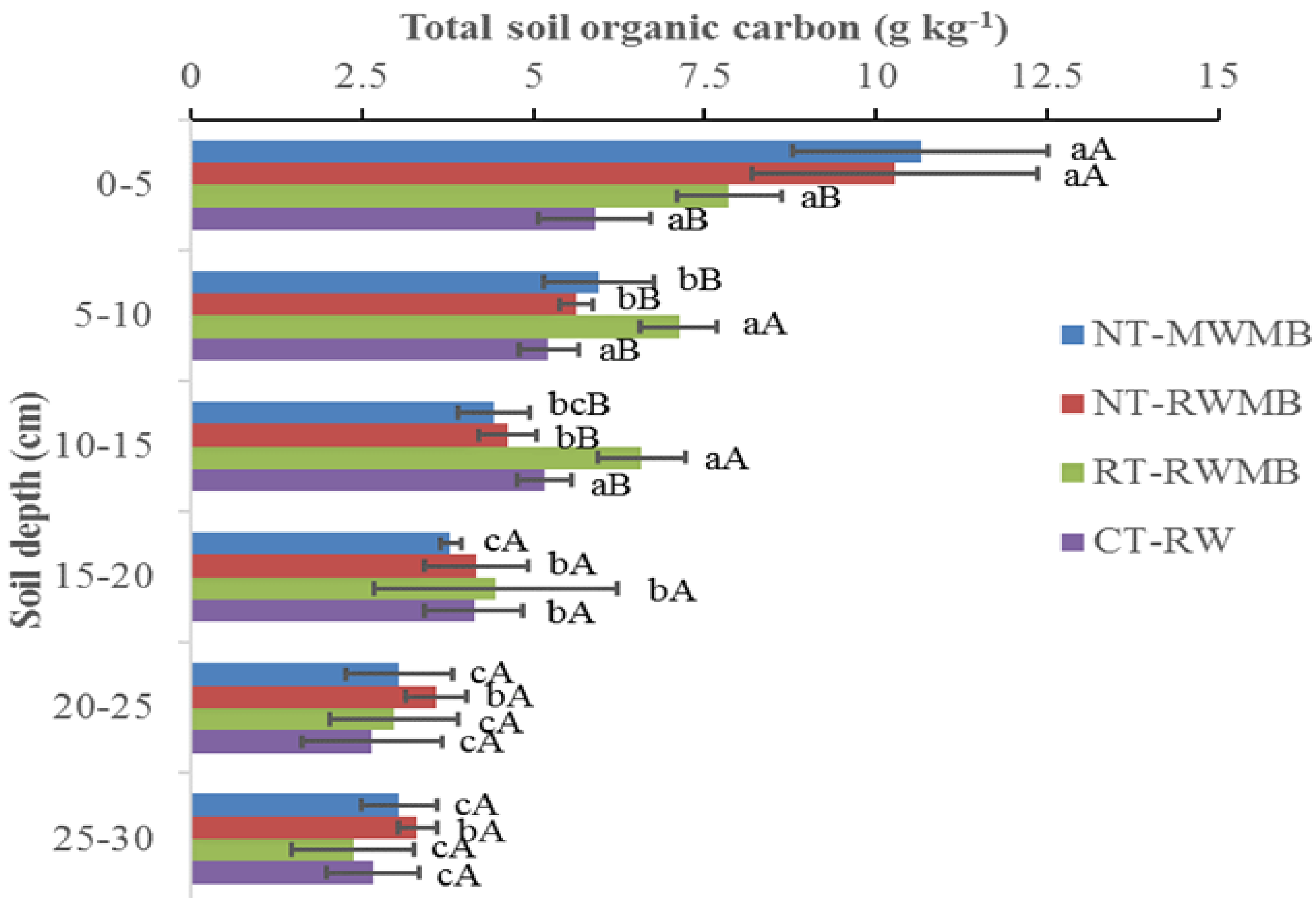






Nature Scientific Reports 7: *9342 (2017)*

Total SOC concentrations under different management systems



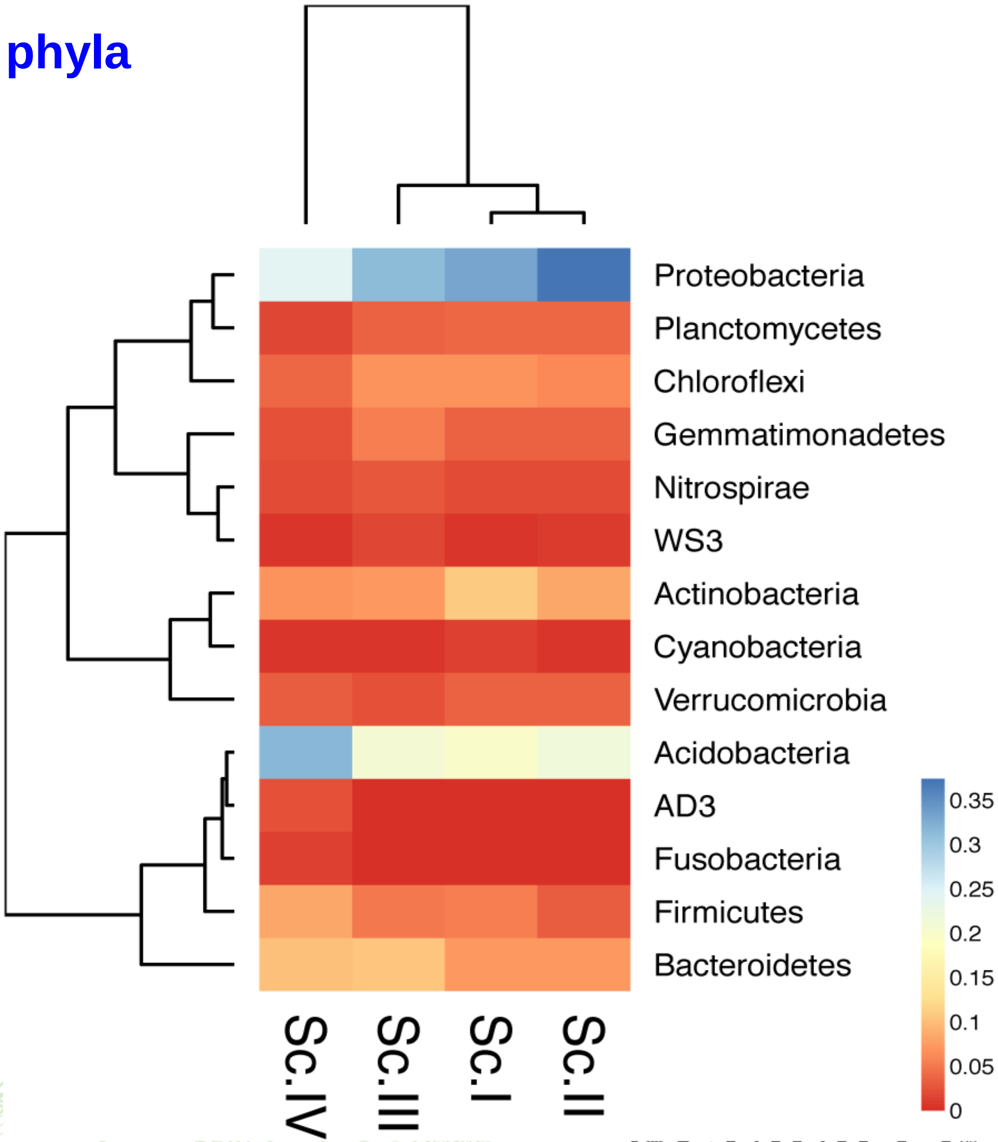
The various small letters indicate significant differences among the soil depths, and the capital letters indicate significant differences among the treatments (P<0.05)

Patra et al (ICAR-CSSRI-CIMMYT-UNU, Germany) collaboration

Metagenomics: Soil bacterial communities under CA and conventional management

Heat map: distribution of dominating phyla in different management scenarios

- Alphaproteobacteria- Nitrifying (Nitrosomonas, nitrobacter), Rhizobium
- Gammaprotobacteria- N fixation (Azotobacter), Pseudomonas
- Betaprotobacteria- S oxidizing- thiobacillus
- Fermicutes- PGPR- Bacillus



Choudhary et al (2018)

Adapting to Climatic Risks: Direct Seeded Rice

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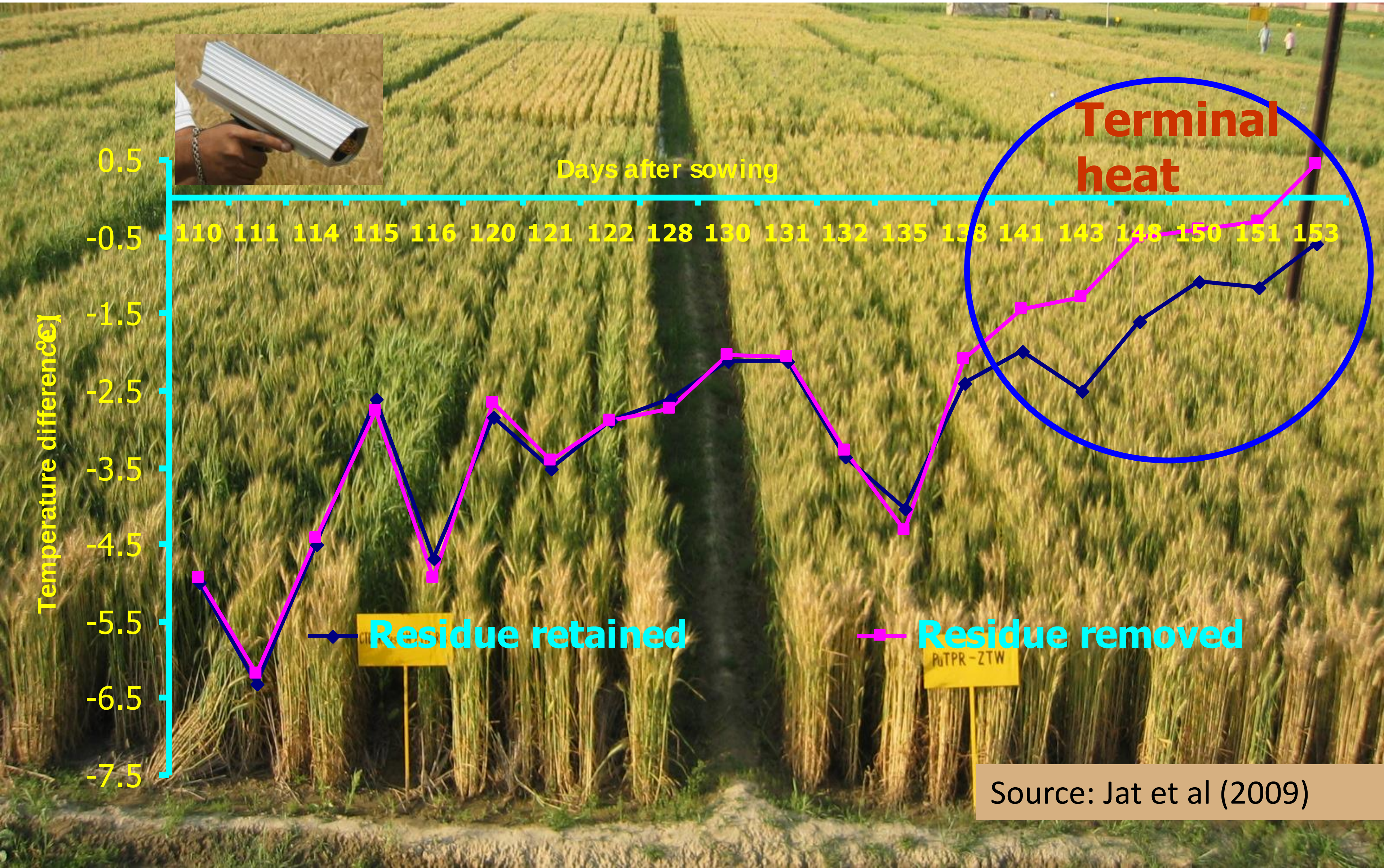
CA in Wheat Systems Adapting to Terminal Heat



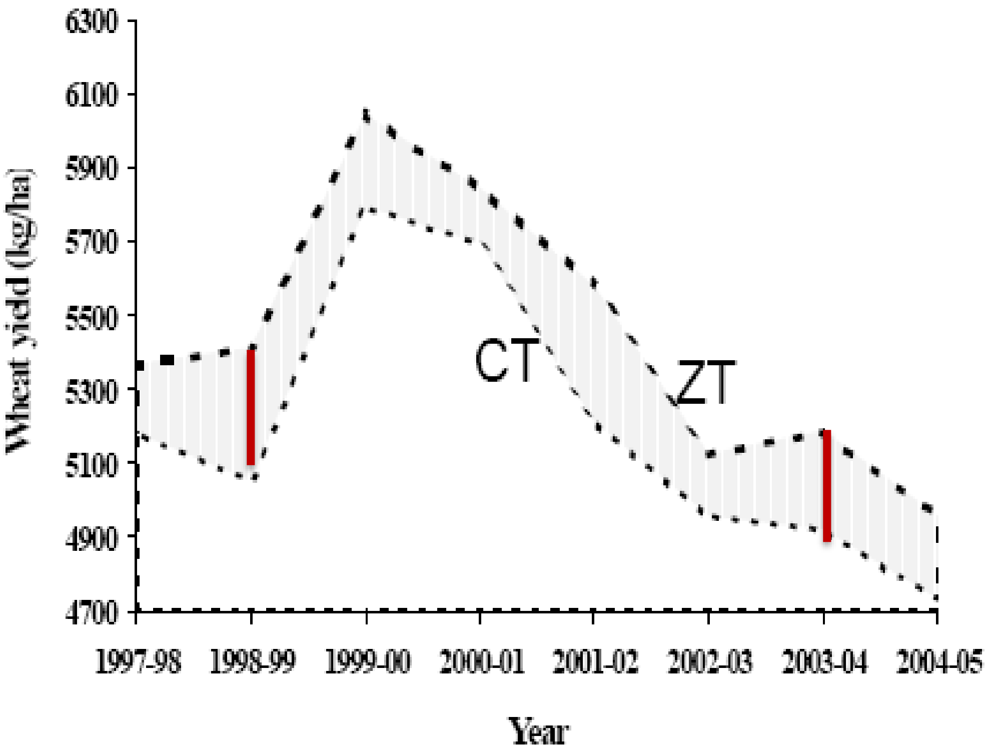
Source: Jat et al (2009)

Conservation Agriculture and Wheat Yields Under Variable Climatic Conditions

March 2004 Heat wave Effects on Wheat Production

State	Yield loss, %	Production loss, million tons
Uttranchal	8.60	0.066
Punjab	8.32	1.287
Haryana	7.62	0.704
Uttar Pradesh	6.75	1.720
Himachal Pradesh	5.79	0.033
Bihar	4.73	0.230
Rajasthan	3.87	0.213
Madhya Pradesh	1.11	0.084
Maharashtra	0.00	0.000
West Bengal	0.00	0.000
India		4.387

Wheat yields under ZT and CT in different years in NW IGP



Source: Gupta et al (2007)

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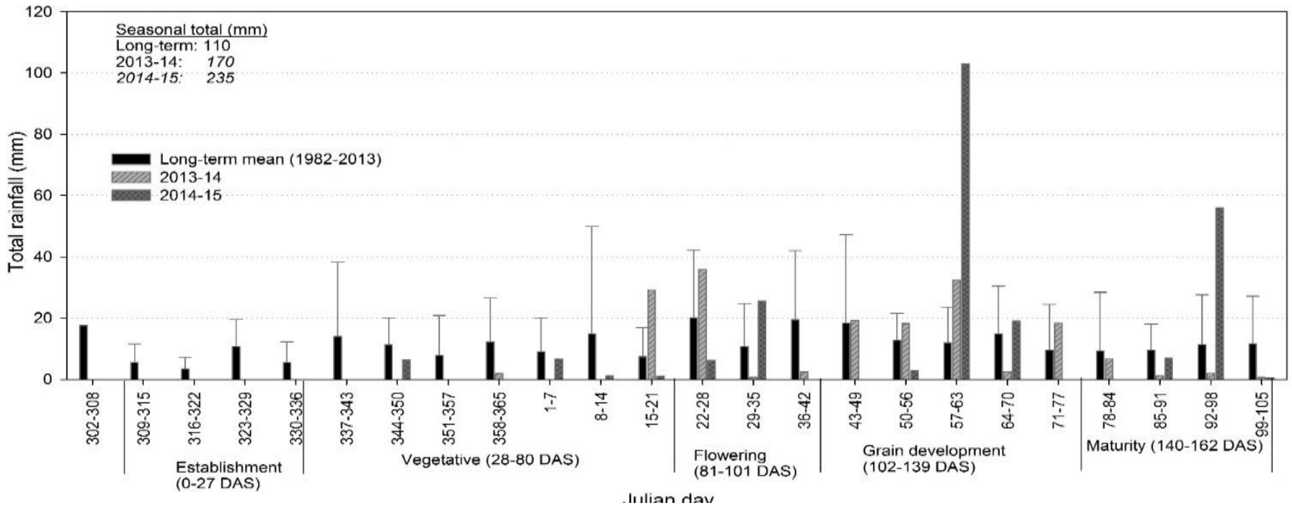
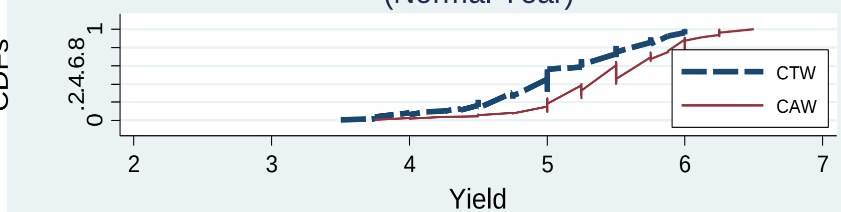
No-till Wheat Under Extreme Climate Risks:

(Excess Rains at Wheat Grain Filling in 2014-15)

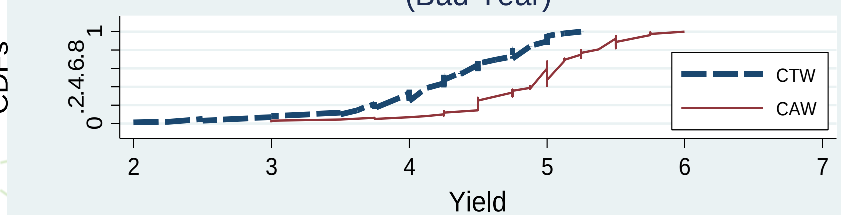
Landscape Scale Evidence on How CA is Climate Smart : a case of climate risks in wheat during 2014-15 in Western IGP



Wheat yield in Haryana in 2013-14 (Normal Year)



Wheat yield in Haryana in 2014-15 (Bad Year)



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Conservation agriculture-based wheat production better copes with extreme climate events than conventional tillage-based systems: A case of untimely excess rainfall in Haryana, India

CrossMark

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Tek Bahadur Sapkota, Mitigation Agronomist[a], Clare Maeve Stirling, Senior Agronomist[b],
M.L. Jat, Senior Cropping Systems Agronomist[a], Hanuman S. Jat, Senior Agronomist[c],
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[b] International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico
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January 2019: Ludhiana, India

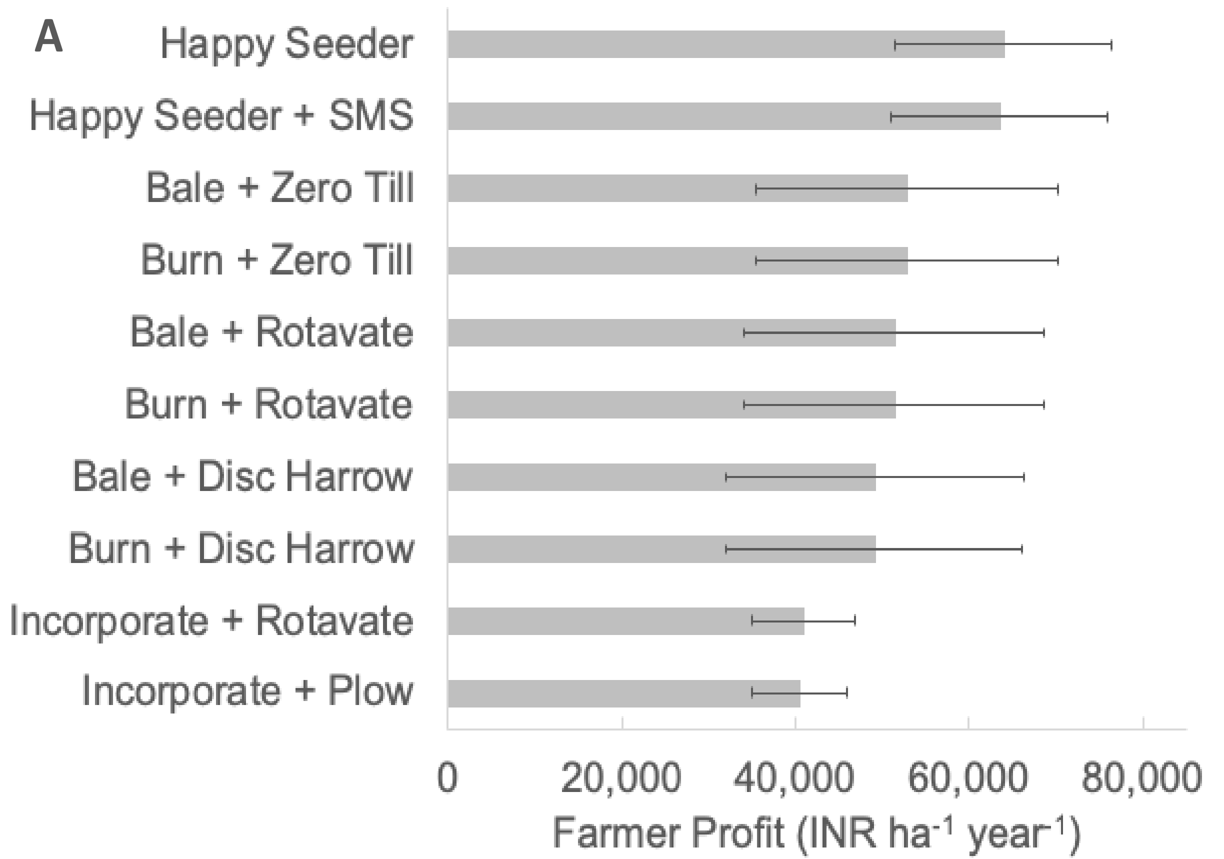
CA in Maize Systems: Adapting to Climate Risks (200+ mm in 3 days in end of June 2017) in Haryana, India

Source: Jat et al (2018)


Substitution

India Has Profitable Alternatives to Crop Burning That Can Help Farmers and Reduce Air Pollution

Substitution with CA based Technological Options



Shyamsundar, Springer, Tallis, Polasky, Skiba, Jat et al, **Science**- Under process

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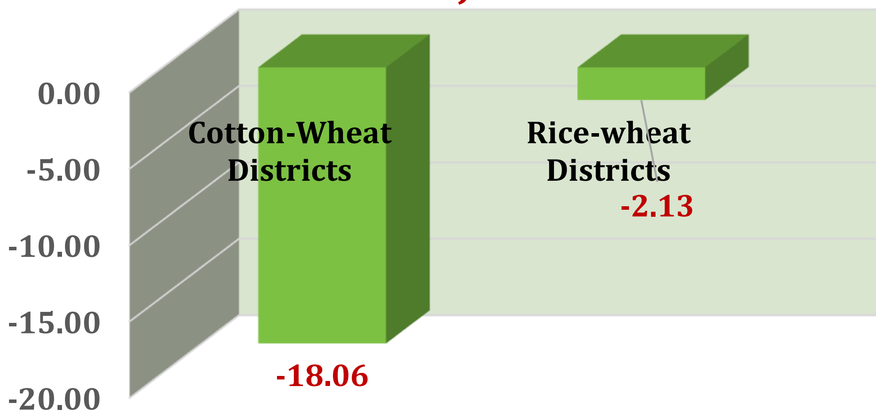
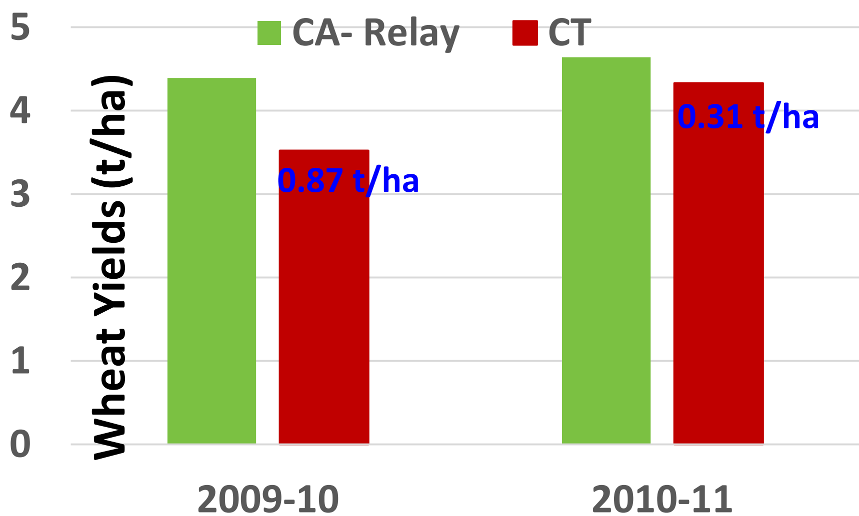
CA in Cotton-Wheat Systems

Wheat yield loss (%) in 2009-10 (Terminal Heat) over 2008-09 in Indian Punjab





- Cotton-wheat, 2nd largest wheat systems in South Asia (>4.5 mha)
- In CW system, wheat is more prone to terminal heat than that of RW
- CA based intensification through relay planting

[Expl. Agric. 49: 19-30 (2013); Expl. Agric. (2016); Field Crops Res. 199: 31-41(2016); Applied Engg. Agric. 32: 341-352 (2016)]

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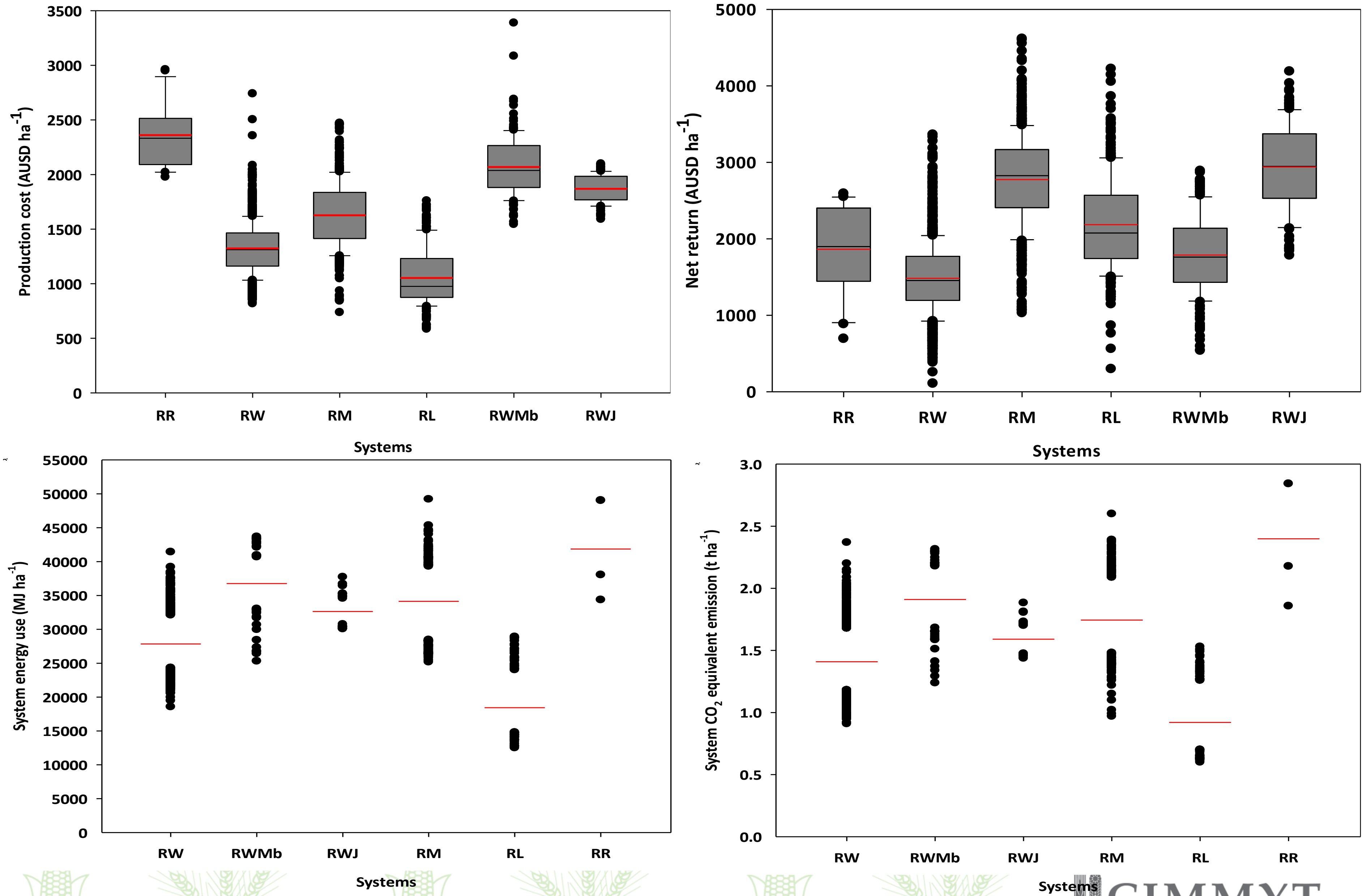
Substitution opportunities: Eastern IGP



Source: Gathala et al (2019)-CIMMYT

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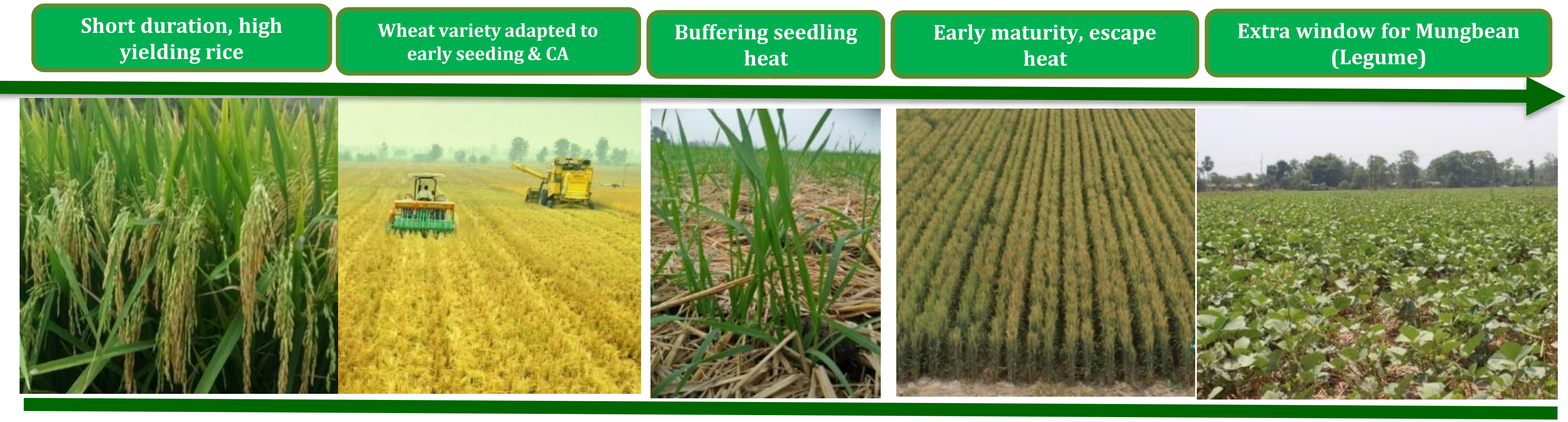
ReDESIGN

Windows of Opportunity for Sustainable Intensification through CA based system optimization approach



- **System approach solutions**
- **High system productivity, profits, resource (water, nutrient) use efficiency**
- **Ensuring nutrition through legumes**
- **System sustainability and soil resilience**

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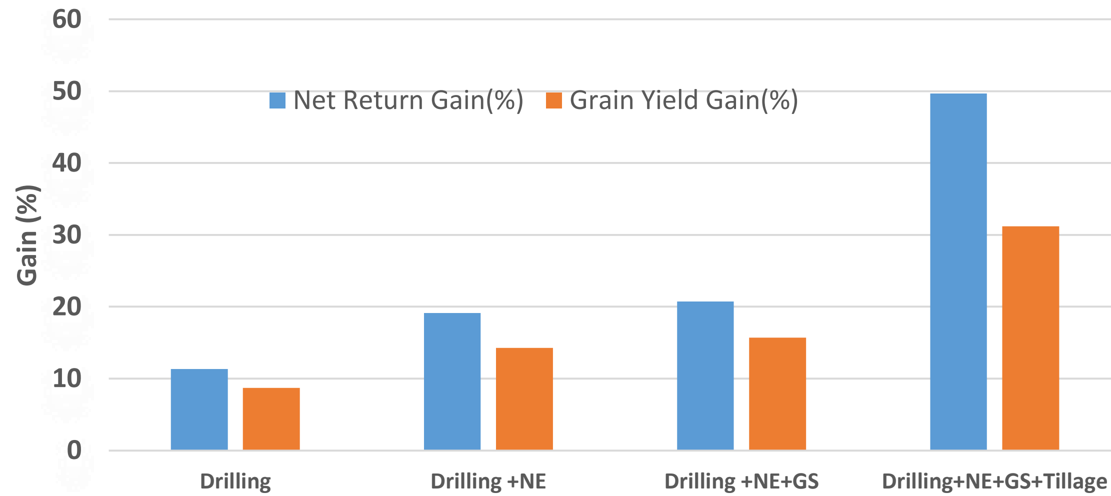
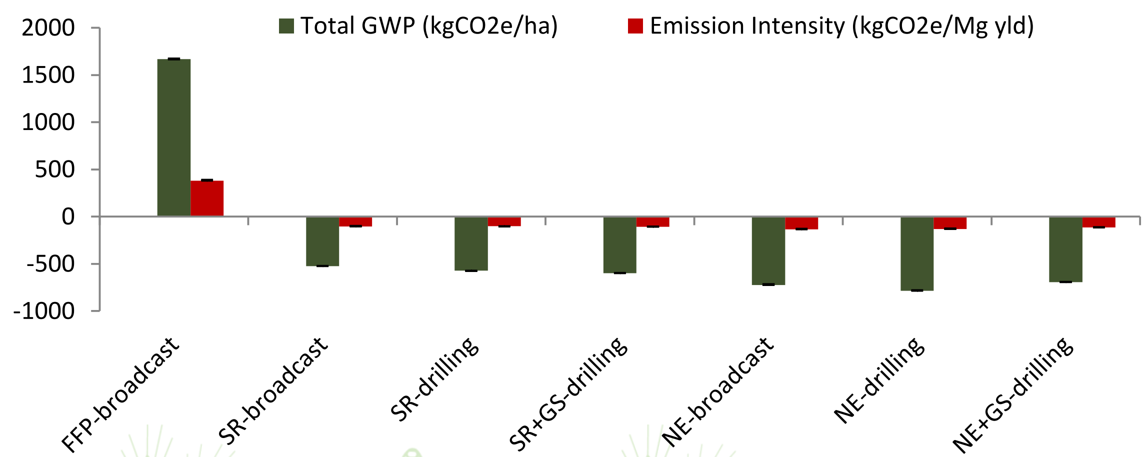
Innovative packaging for sustainable intensification portfolio
(CA+ Diversification+ precision water & N)

Scenarios	Grain yield (t ha^{-1})			Irrigation water use (mm ha^{-1})		
	Rice/ Maize	Wheat	System	Rice/ Maize	Wheat	System
Conv RW system-Flood	7.04a	5.68b	13.36b	1886a	435a	2321a
CA- RW system-Flood	5.87b	6.47a	13.06b	1447b	385a	1832b
CA- RW system+ SSDI	6.30b	6.70a	13.75a	785c	207b	992c
CA- MW system- Flood	7.14a	6.51a	14.38a	110d	372a	482d
CA -MW system + SSDI	7.48a	6.59a	14.81a	85d	198b	283e

Source: ICAR-CSSRI-CIMMYT Collaborative Research @ Karnal, Haryana, India

Precision Nutrient Management in CA: Example from *Eastern IGP*





Source: Jat et al (Forthcoming)

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Green solutions for addressing the food-energy-water (FEW) nexus in western IGP

Scenario	System yield (rice eq) (t/ha)	System irrigation water use (cm)	WPi (kg grain m^{-3} water)	Net return, (Rs/ha/yr)	Energy use (kWh)	GHG (Kg CO_2 eq. ha^{-1} $year^{-1}$
RWCT-FP	11.79cd	208.61a	0.58e	128402	3995	3680
RWZT-FL	11.72d	193.22b	0.61e	135338	3702	3530
RWZT-SSD	12.06c	109.98c	1.11d	143058	3551	0
MWCT-FP	11.87cd	75.38d	1.60c	123305	1665	1655
MWPB-FU	12.43b	61.70e	2.03b	138324	1356	1348
MWPB-SSD	12.93a	35.14f	3.70a	147612	1196	0

Jat et al (2018): CIMMYT-BISA-PAU Collaborative Research @ Ludhiana, Punjab, India

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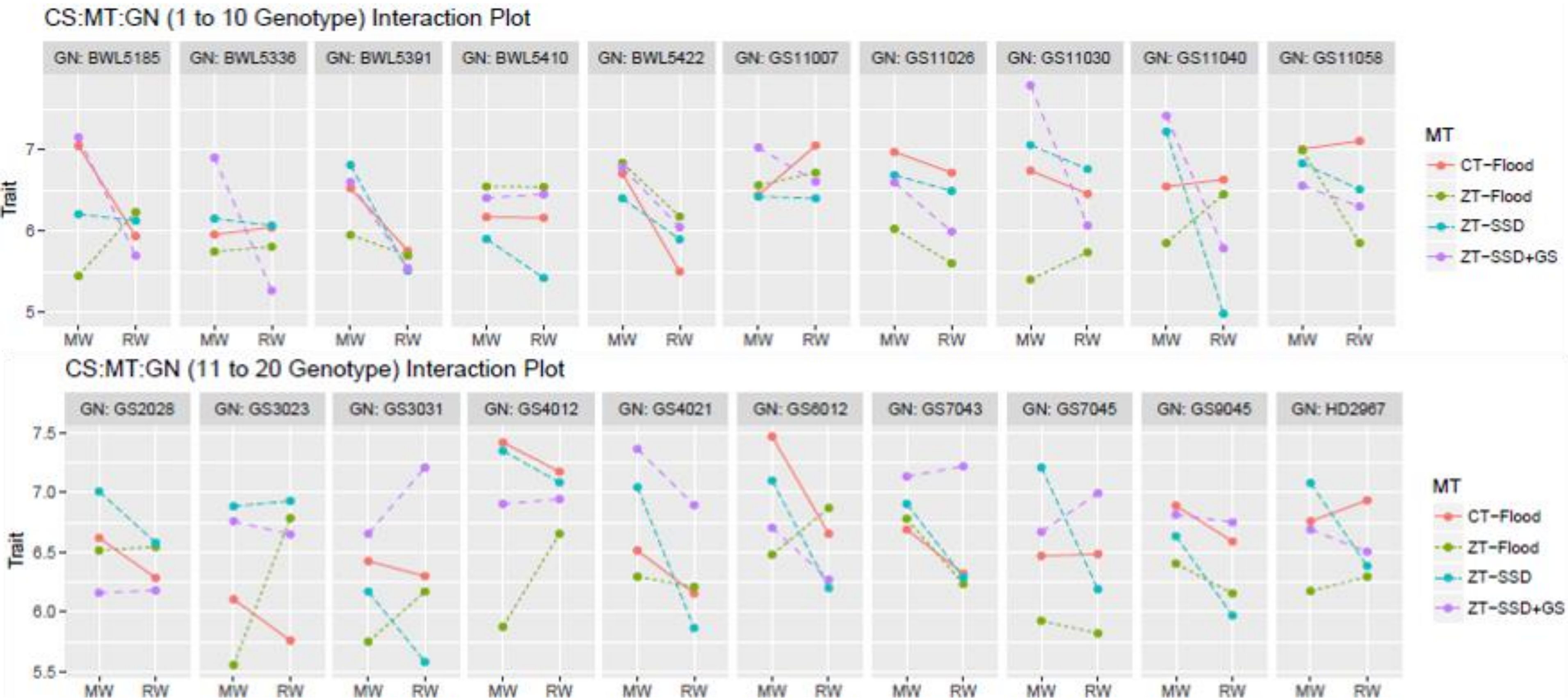
Genotype x Environment x Management:
Opportunities for realizing yield potential



- **Significant interactions of genotypes with cropping systems and management**
- **For targeting genotypes for future agronomic domains considering future residue scenario, G x E x M research is important for realizing the potential of genotypes**

Source: Sidhu, Jat et al

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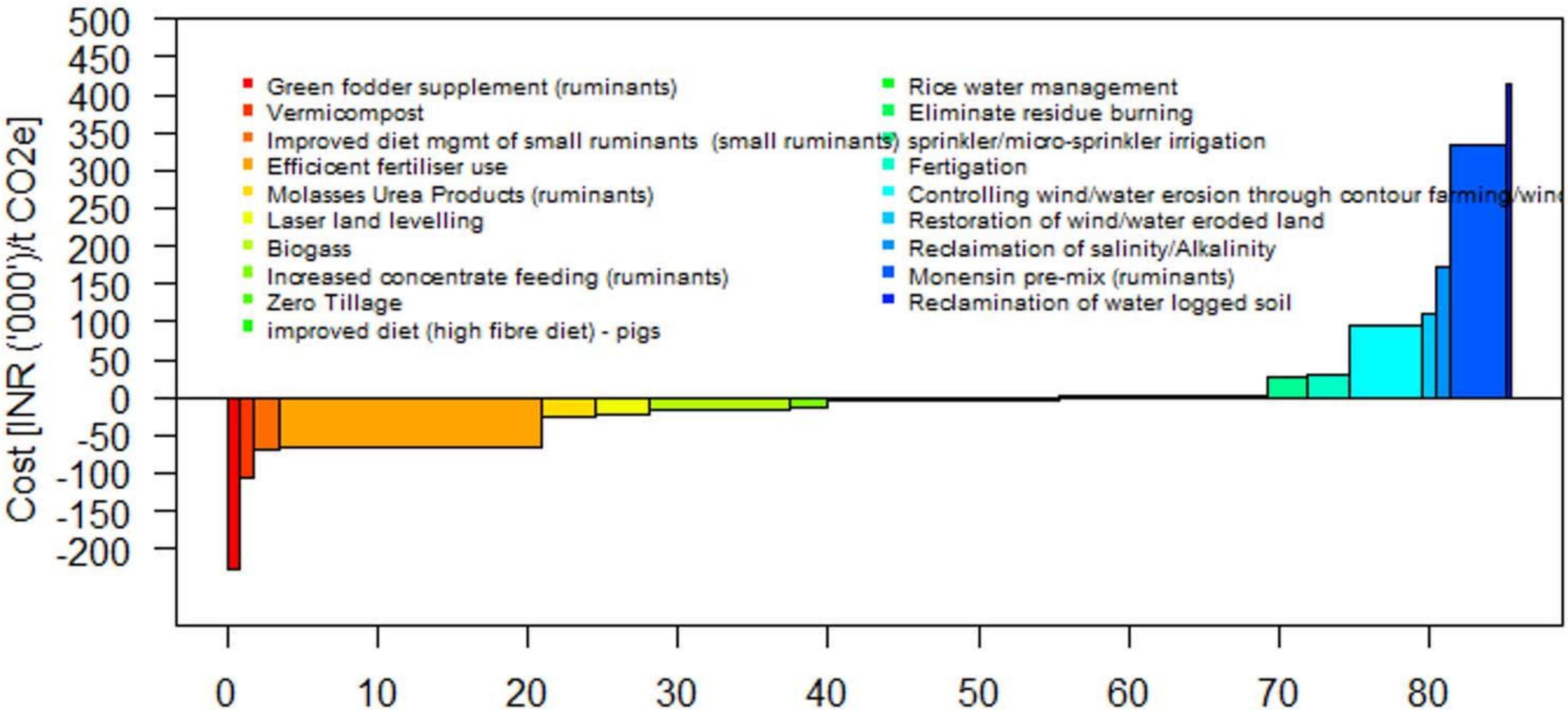
Cost-effective opportunities for climate change mitigation in Indian Agriculture: NRM/CA systems on lead



- Technical Mitigation potential = 85.5 $MtCO_2e$/year
- 40 $MtCO_2e$/year is related to NRM specially CA, nutrient, water mgt
- 80% of mitigation potential achieved via cost saving options

Sapkota, Vetter, Jat et al; *Science of the Total Environment* 655 (2019) 1342–1354

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Moving from Single Technology to Portfolio of Practices

Agricultural Water Management 202 (2018) 122–133

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Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Performance of portfolios of climate smart agriculture practices in a rice-wheat system of western Indo-Gangetic plains

Check for updates

S.K. Kakraliya[a], H.S. Jat[b], Ishwar Singh[a], Tek B. Sapkota[b], Love K. Singh[c], Jhabar M. Sutaliya[b], Parbodh C. Sharma[d], R.D. Jat[b], Meena Choudhary[e], Santiago Lopez-Ridaura[f], M.L. Jat[b,*]

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Systems productivity
Water productivity

ABSTRACT

Several resource use efficient technologies and practices have been developed and deployed to address the challenges related to natural resource degradation and climatic risks management in rice-wheat (RW) rotation of Indo-Gangetic Plains (IGP). However, the practices applied in isolation may not be effective as much as in combination due to changing input responses under varied weather abnormalities. Therefore, a multi-location farmer's parti-

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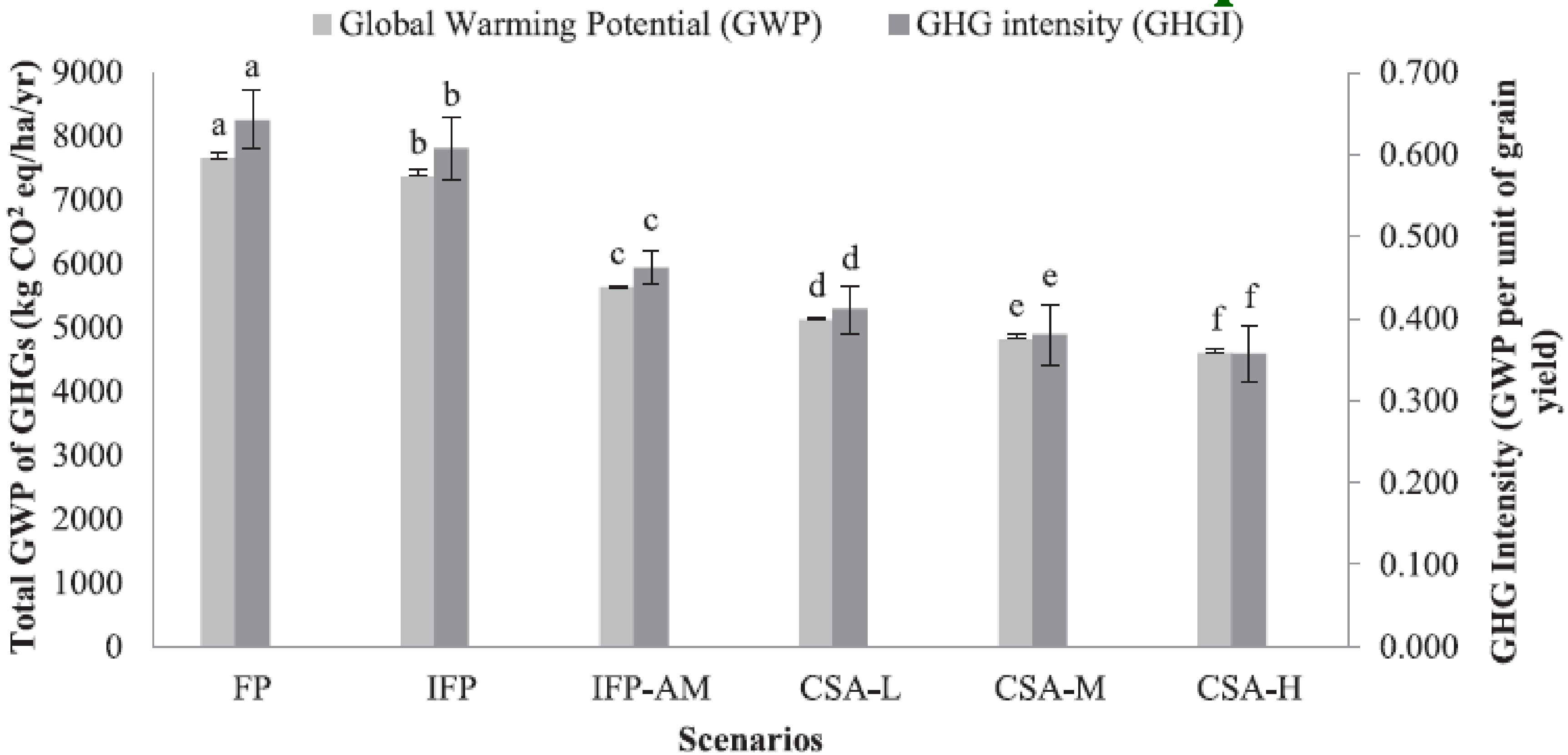
Portfolio of Practices-Example



Yield	↔	↔	↑	↑	↑	↑
Income	↓	↓	↑	↑	↑	↑
Water	↑	↑	↓	↓	↓	↓
Energy	↑	↑	↓	↓	↓	↓
Adaption	↔	↔	↔	↑	↑	↑

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CSA Matrix of different technologies

CSAPs	Adapt (3)	Mitig (3)	Yield/income (3)	Mat. Tech Dev (2)	Adop. dom (2)	Farmer accep (3)	Social & gender impl (2)	Innovation strength (1)	Lever by R&D inst. (1)	Policy backup (1)	Results with No weights (Maximum of 40 points)	Results with No weights as fraction of maximum attainable	weighted
LLL	2	3	2	4	3	4	3	3	4	4	32	0.80	64
NT	3	3	2	4	3	3	3	3	3	2	29	0.73	61
RM-HS	3	4	2	4	3	3	3	3	3	4	32	0.80	66
DSR	3	3	1	3	3	2	3	3	2	2	25	0.63	52
PNM-NE	2	4	2	4	3	2	3	3	1	2	26	0.65	56
PNM-GS	2	4	2	4	3	2	3	3	1	1	25	0.63	55
Legume	2	3	3	3	3	2	3	3	3	2	27	0.68	56
RBP	3	2	2	4	4	2	2	3	2	1	25	0.63	53
AWD	3	3	2	4	4	2	3	3	2	1	27	0.68	58
Agro-forestry	3	4	2	3	3	2	3	3	2	3	28	0.70	59
STW-Var	3	1	2	4	4	3	3	3	3	2	28	0.70	57
STM-Var	3	1	2	4	4	3	3	3	2	2	27	0.68	56
STR-Var	3	1	2	4	4	3	3	3	3	2	28	0.70	57

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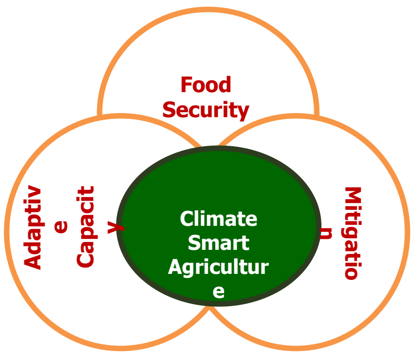
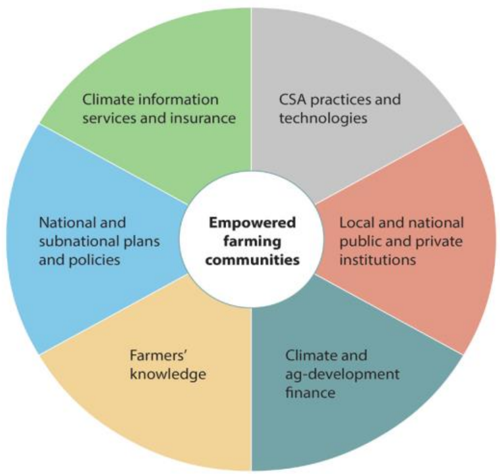
CLIMATE SMART VILLAGE (CSV) PROGRAM

“A community based holistic approach for empowering farm families for building resilience against climatic risks”





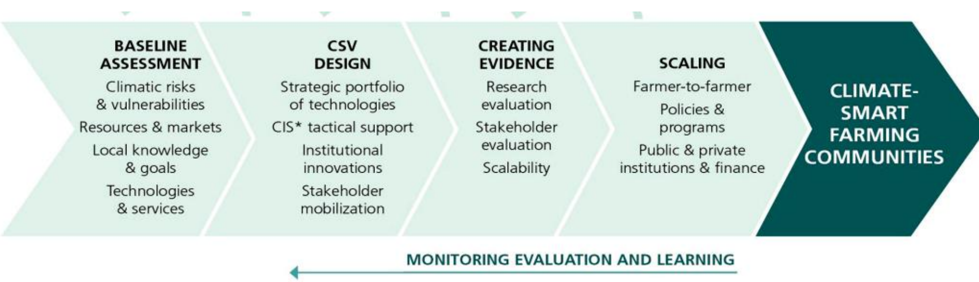
Weather Smart
Weather forecast, Weather insurance, Agro - advisories, climate analogues

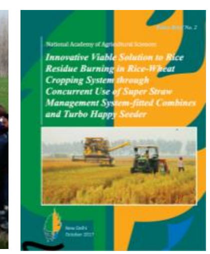
Water Smart
Direct seeded rice, maize based system, raised beds, precision land levelling,

Carbon and nutrient Smart
No-tillage, Residue Management, Legumes, Green seeker, NE

Energy Smart
No-tillage, Residue Management, DSR Precision water management

Knowledge Smart
ICTs, Gender Empowermen, Capacity development, Women and youth focus





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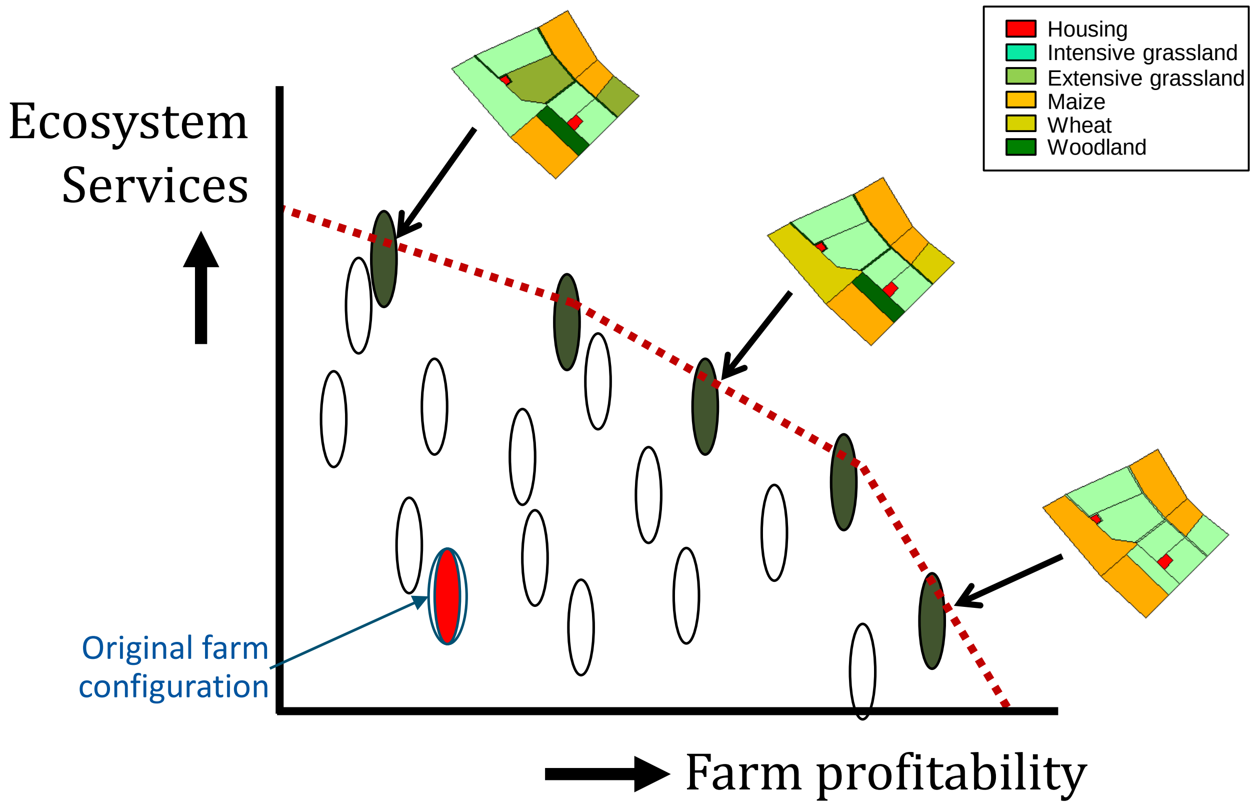
Science of Scaling for impact at Scale

Targeting with Clarity of Objectives



Business Models for Scaling

Journal of Cleaner Production 210 (2019) 1109–1119

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Journal of Cleaner Production

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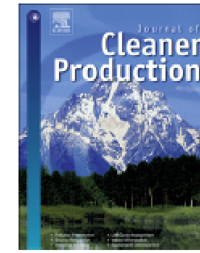

Business models of SMEs as a mechanism for scaling climate smart technologies: The case of Punjab, India

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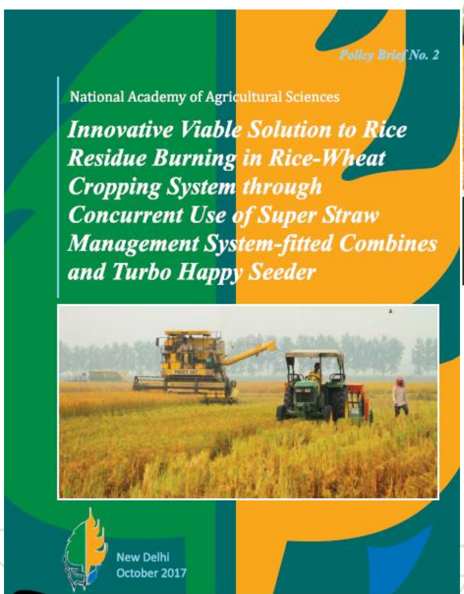
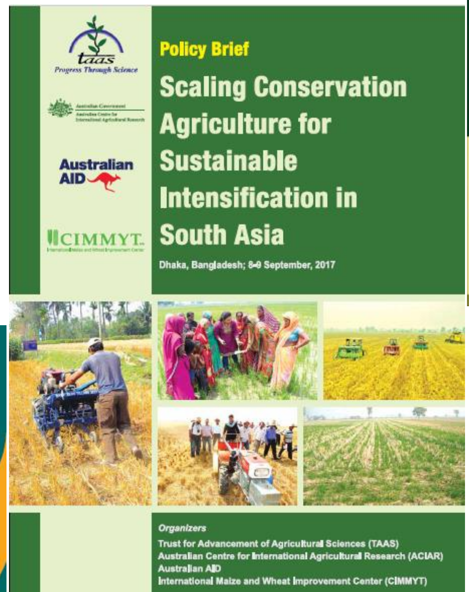
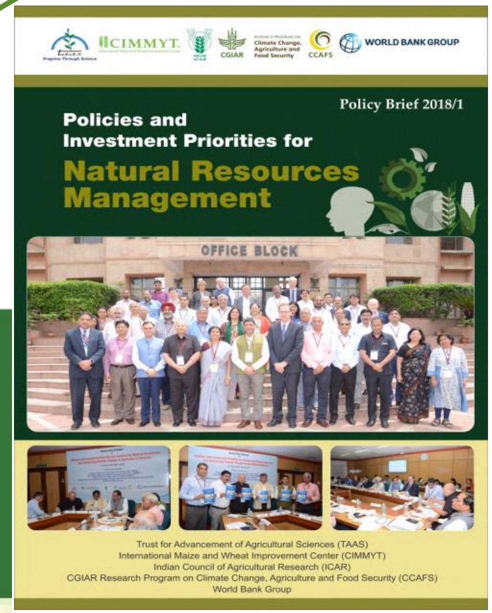
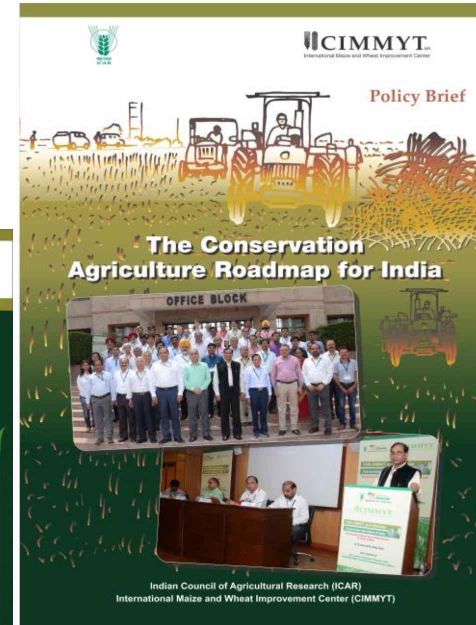
Research Evidence are Filling in to Policy for Scaling









Natural Resource Management Mediated Evergreen Revolution

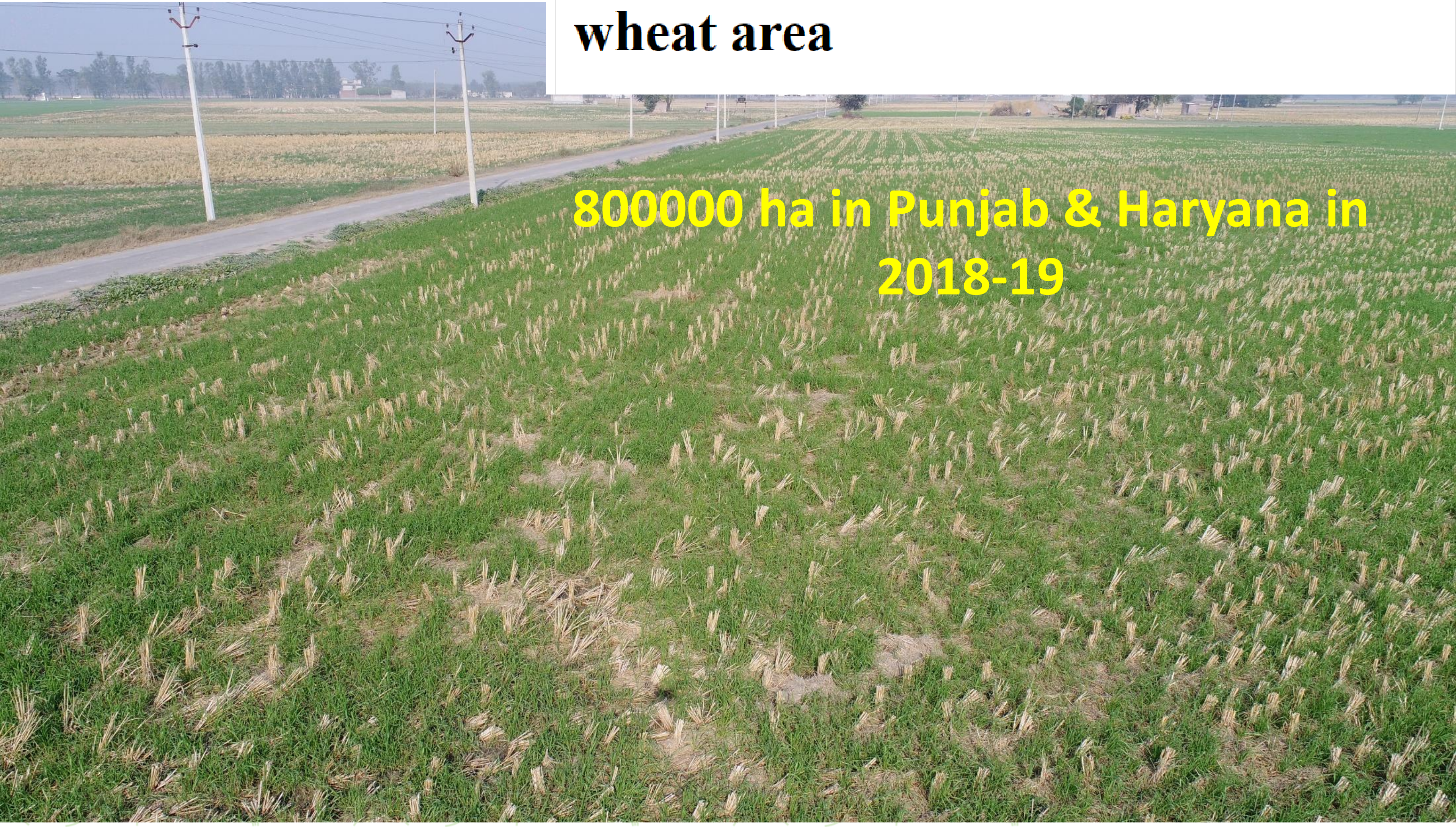
CIMMYT

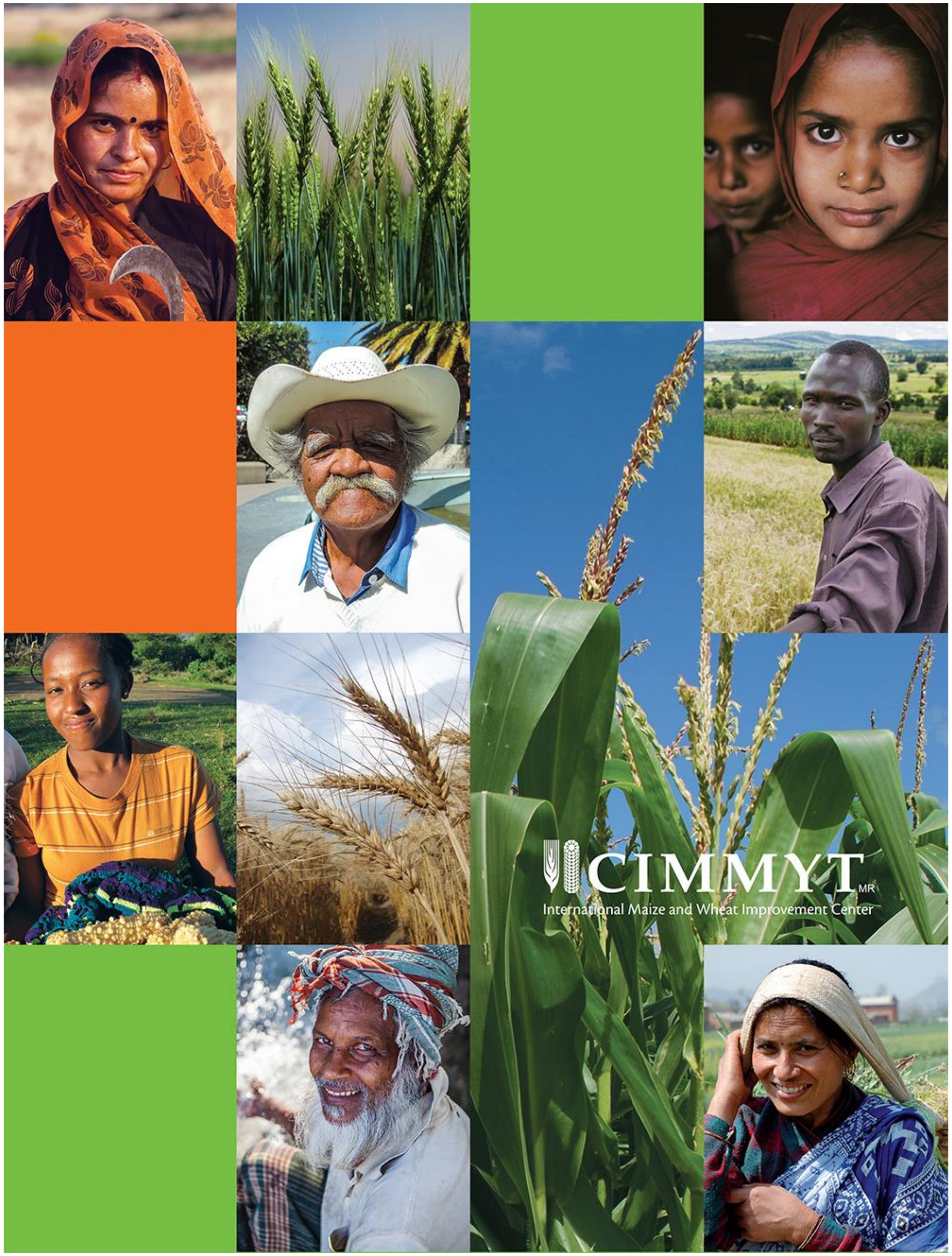
Impact at scale

The Indian EXPRESS

Tuesday, December 25, 2018

Punjab agriculture secretary: Direct sowing in 17 per cent of wheat area





Thank you for your interest!

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