Advancements in Nutrient Management Research under Conservation Agriculture

ML Jat

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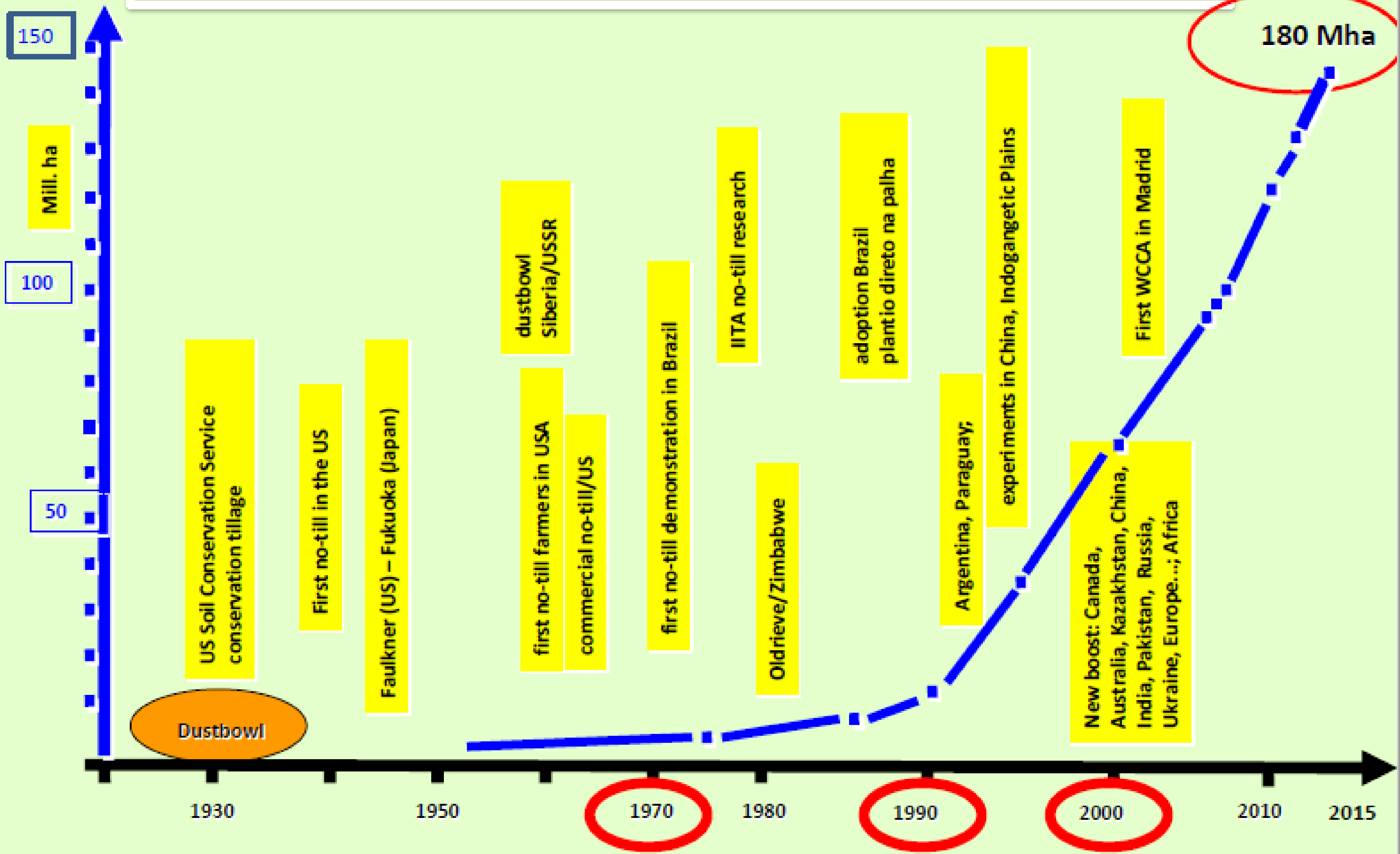
International Maize and Wheat Improvement Center CIMMYT

Presentation outline

- Background info on Conservation Agriculture (CA)
- CA and soil properties
- CA and soil properties- Temporal Changes
- Nutrient response in CA
- Examples of recent research on nutrient management in CA
  - ✓ Rate-NE, GS etc
  - ✓ Time- optimization results
  - ✓ Method- fertigation, drilling
- Big picture of nutrient management
- Summary & way forward

History and Adoption of CA (2015/16). Since 2008/09 increasing at 10 M ha annually



Source: Kassam et al (2018)

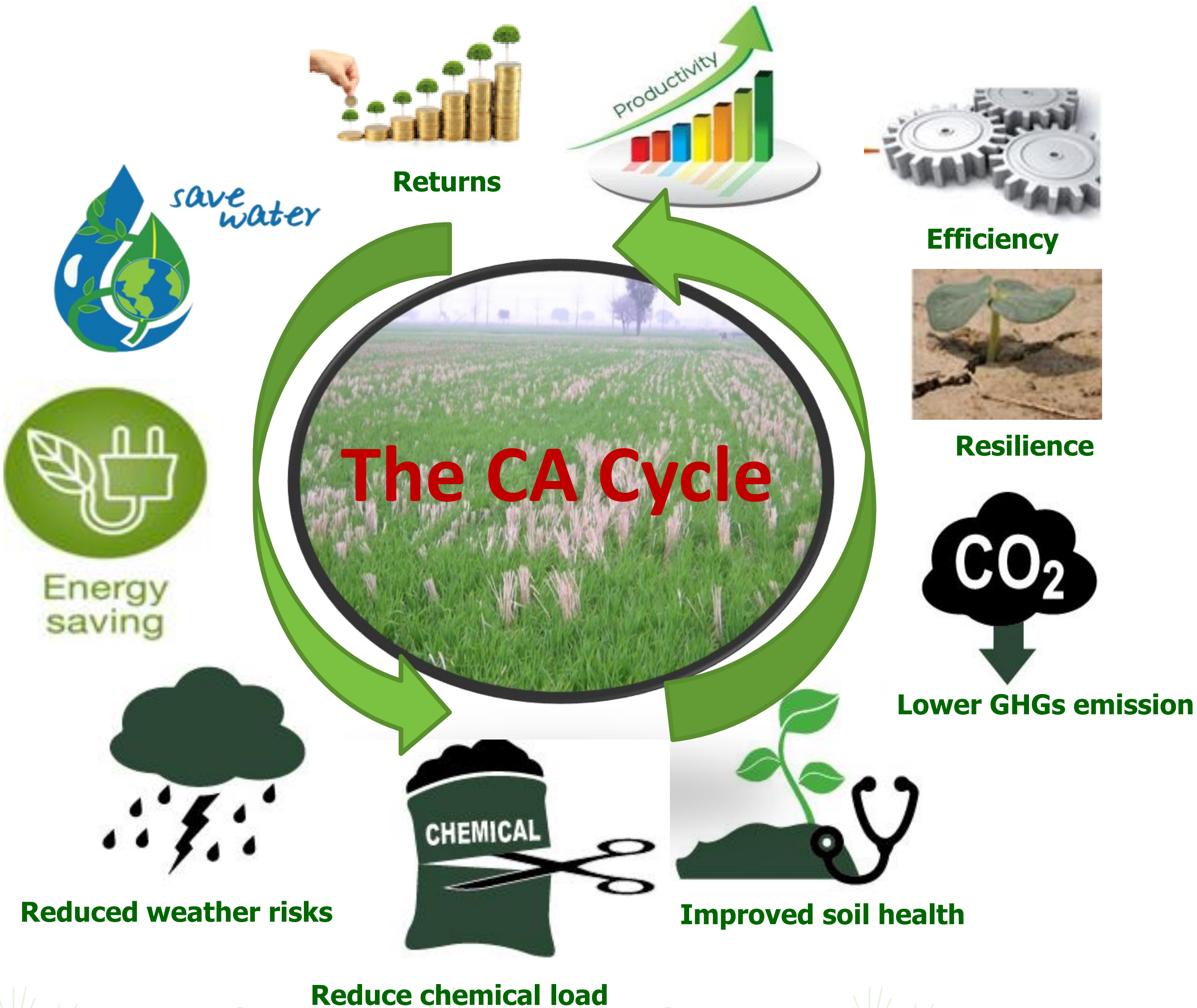
Area of cropland under CA by continent – 2015/16

(source: FAO AquaStat: www.fao/ag/ca/6c.html & personal database)

Continent	Area (Mill. ha)	Per cent of global total	Per cent of arable land of reporting countries
South America	69.9 (49.6)*	39.0 (40.9)#	63.2
North America	63.2 (40.0)	35.2 (58.0)	28.1
Australia & NZ	22.7 (12.2)	12.7 (86.1)	45.5+
Asia	13.2 (2.6)	7.4 (408)	3.8
Russia & Ukraine	5.2 (0.1)	2.9(5000)	3.3
Africa	2.7 (0.5)	1.5 (447)	2.0
Europe	2.5 (1.6)	1.4 (56.3)	3.5
Global total	179.5 (107)* ( )* 2008/9	100 (69.2)# ( )# % change since 2008/09	12.5 (7.4)* %global cropland + includes non-cropland

~50% in developing regions, ~50 % in industrialized regions

Source: Kassam et al (2018)


Returns
Productivity
save water
Efficiency
Resilience
The CA Cycle
Energy saving
CO2
Lower GHGs emission
CHEMICAL
Reduced weather risks
Improved soil health
Reduce chemical load

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Changes in Soil Properties

- **Soil Carbon**
- **Chemical properties and nutrient availability**
- **Physical properties**
- **Soil biology**
- **Nutrient response**

3 Biotech (2018) 8:304
https://doi.org/10.1007/s13205-018-1317-9

ORIGINAL ARTICLE

CrossMark

Soil bacterial diversity under conservation agriculture-based cereal systems in Indo-Gangetic Plains

Madhu Choudhary[1] · Parbodh C. Sharma[1] · Hanuman S. Jat[2] · Abhinandita Dash[3] · Balaji Rajashekar[3] · Andrew J. McDonald[4] · Mangi L. Jat[2]

CSIRO PUBLISHING
Soil Research
https://doi.org/10.1071/SR16357

Soil biochemical changes at different wheat growth stages in response to conservation agriculture practices in a rice-wheat system of north-western India

Tanushree Bera[A], *Sandeep Sharma*[A,D], *H. S. Thind*[A], *Yadvinder-Singh*[B,C], *H. S. Sidhu*[B], *and M. L. Jat*[C]

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Science of the Total Environment 640–641 (2018) 1382–1392

Contents lists available at ScienceDirect

Science of the Total Environment

ELSEVIER

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Long-term impact of conservation agriculture and diversified maize rotations on carbon pools and stocks, mineral nitrogen fractions and nitrous oxide fluxes in inceptisol of India

C.M. Parihar[a,b], M.D. Parihar[c], Tek B. Sapkota[d], R.K. Nanwal[c], A.K. Singh[a], S.L. Jat[a], H.S. Nayak[b], D.M. Mahala[a], L.K. Singh[d], S.K. Kakraliya[c,d], Clare M. Stirling[e], M.L. Jat[d,*]

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Geoderma 313 (2018) 193–204

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Geoderma

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

Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains

CrossMark

Madhu Choudhary[a], Ashim Datta[a], Hanuman S. Jat[b], Arvind K. Yadav[a], Mahesh K. Gathala[c], Tek B. Sapkota[b], Amit K. Das[d], Parbodh C. Sharma[a], Mangi L. Jat[b,*], Rajbir Singh[e], Jagdish K. Ladha[f]

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Applied Soil Ecology 126 (2018) 189–198

Contents lists available at ScienceDirect

Applied Soil Ecology

ELSEVIER

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

Sustainable intensification influences soil quality, biota, and productivity in cereal-based agroecosystems

Madhu Choudhary[a], Hanuman S. Jat[b,*], Ashim Datta[a], Arvind K. Yadav[a], Tek B. Sapkota[b], Sandip Mondal[c], R.P. Meena[d], Parbodh C. Sharma[a], M.L. Jat[b]

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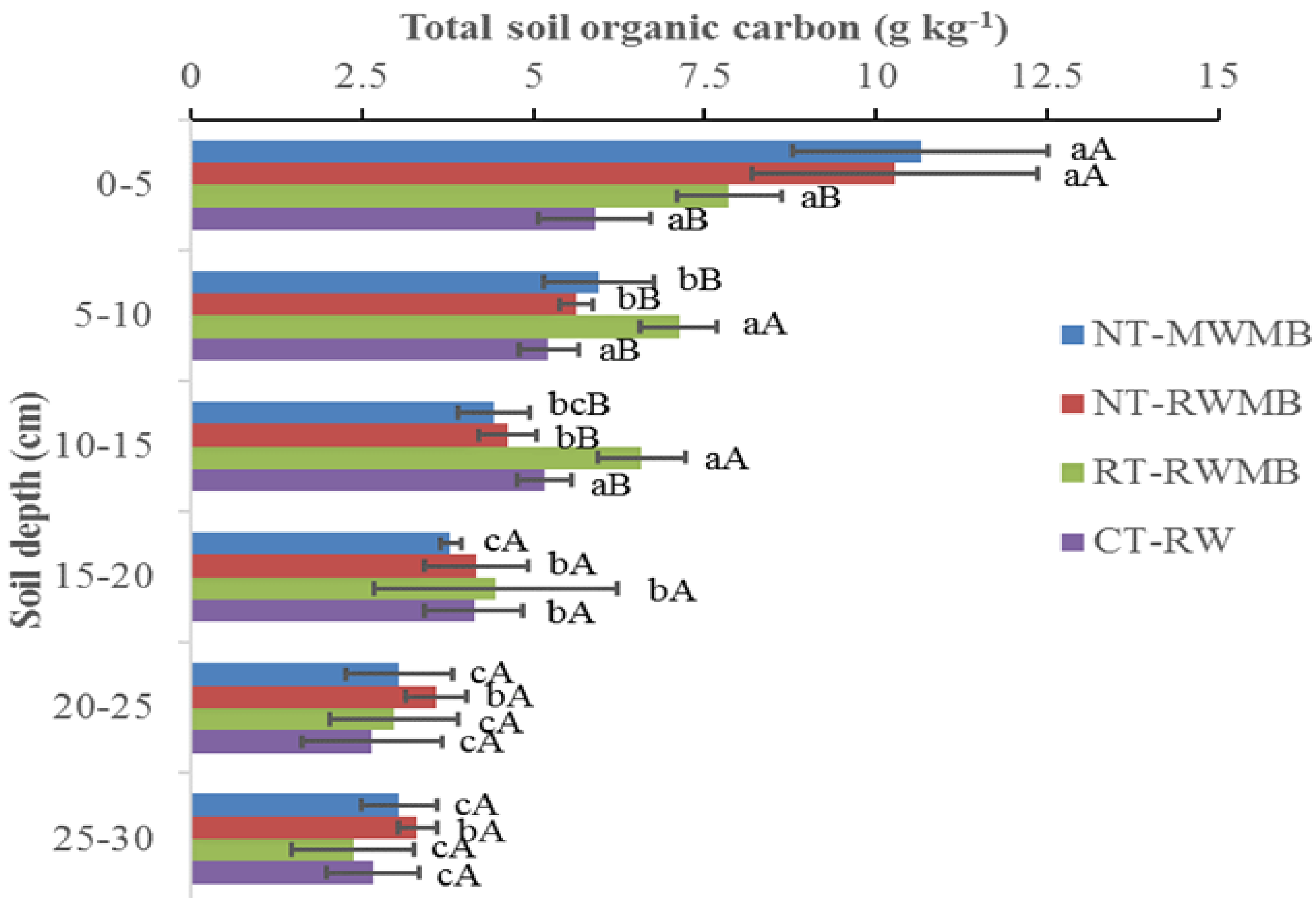
Depth distribution of total SOC concentrations under different management systems



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

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Soil organic carbon sequestration rates (Mg ha^{-1} yr^{-1}) under different scenarios

Soil depth (cm)	Sce4/NT-MWMB	Sce3/NT-RWMB	Sce2/RT-RWMB	Trend
0-5	0.42 (0.12)	0.40 (0.22)	0.18 (0.08)	Sce4 > Sce3>Sce2
0-10	0.49(0.11)	0.44 (0.22)	0.37 (0.14)	Sce4 > Sce3>Sce2
0-15	0.41(0.12)	0.39 (0.19)	0.50 (0.15)	Sce2 > Sce4 > Sce3
0-20	0.38 (0.06)	0.40 (0.14)	0.52 (0.18)	Sce2 > Sce3 >Sce4
0-25	0.42 (0.10)	0.49 (0.20)	0.55 (0.23)	Sce2 > Sce3> Sce4
0-30	0.46 (0.13)	0.56 (0.24)	0.52 (0.31)	Sce3 > Sce2 >Sce4

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

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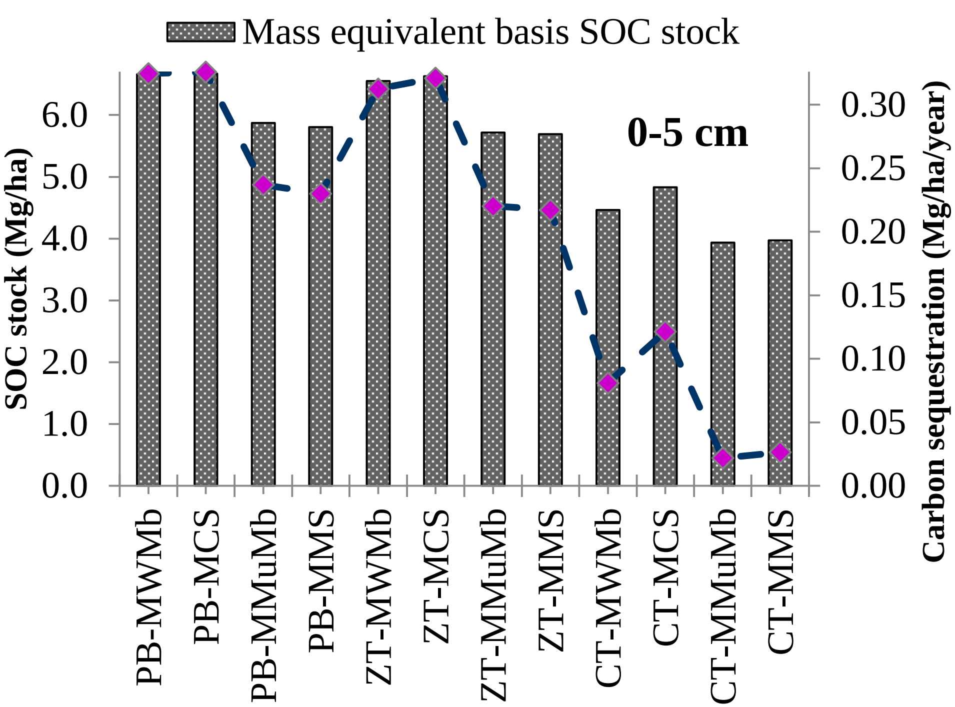
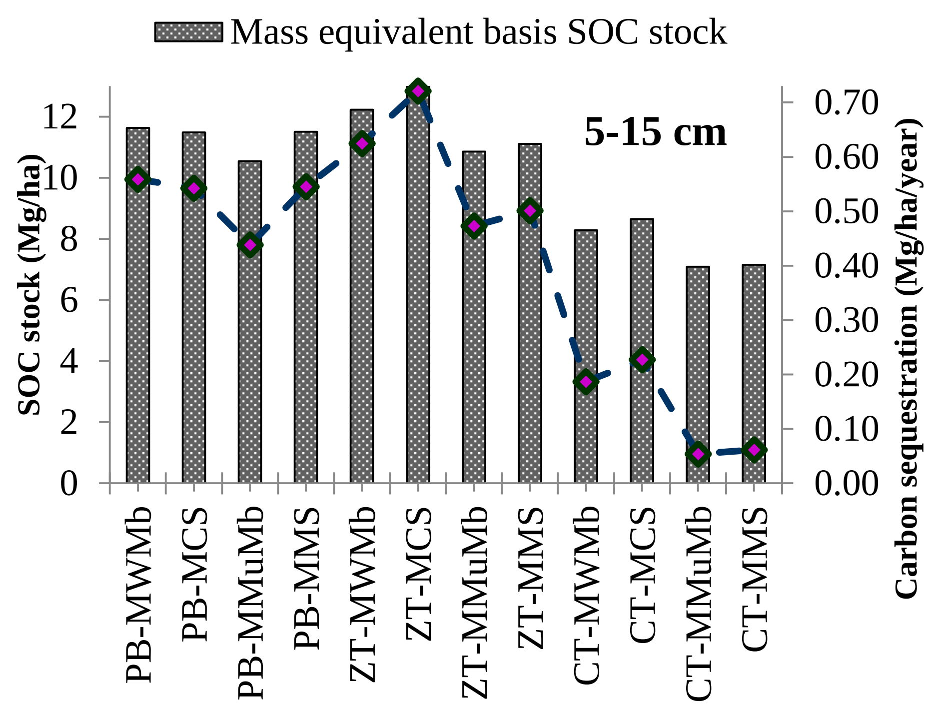
Changes in organic carbon content and stocks in different CA management practices in Bihar, India

Treatments	2015-16		2017-18		
	TOC (g/kg)	Carbon stock (Mg C/ha)	TOC (g/kg)	Carbon stock (Mg C/ha)	C sequestered (Mg C/ha/yr)
			0-5 cm		
CTRW	7.57b	6.76a	8.35c	7.45b	0.35b
ZTRW + R+ MB	9.57a	8.37a	13.3a	11.6a	1.62a
PBMW + R+ MB	10.3a	7.98a	11.1b	8.55b	0.29b
PBMM + R+ MB	10.2a	7.74a	11.0b	8.38b	0.32b
			5-15 cm		
CTRW	4.85b	8.37b	6.58c	11.4b	1.51b
ZTRW + R+ MB	4.79b	8.03b	7.77bc	13.0b	2.06b
PBMW + R+ MB	5.22b	8.97b	13.2a	16.9a	3.97a
PBMM + R+ MB	7.16a	11.7a	9.70b	15.8b	2.50b

Source: CIMMYT-Kyoto University-ICAR-BISA collaboration

Effect of long-term tillage and diversified systems on SOC stock and C-sequestration potential (on equivalent mass basis) after 9 years of continuous cropping





Sandy loam (Inceptisols) of north-west India (semi-arid climate)

Source: Parihar et al (ICAR-IARI/IIMR-CIMMYT collaboration)

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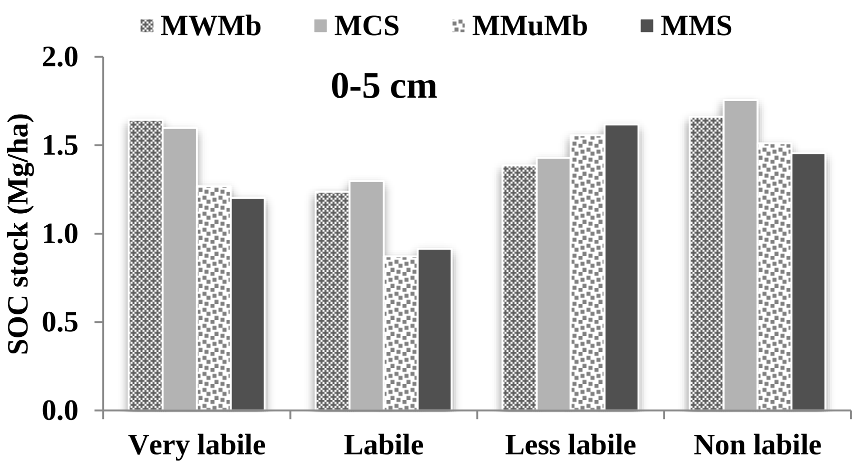
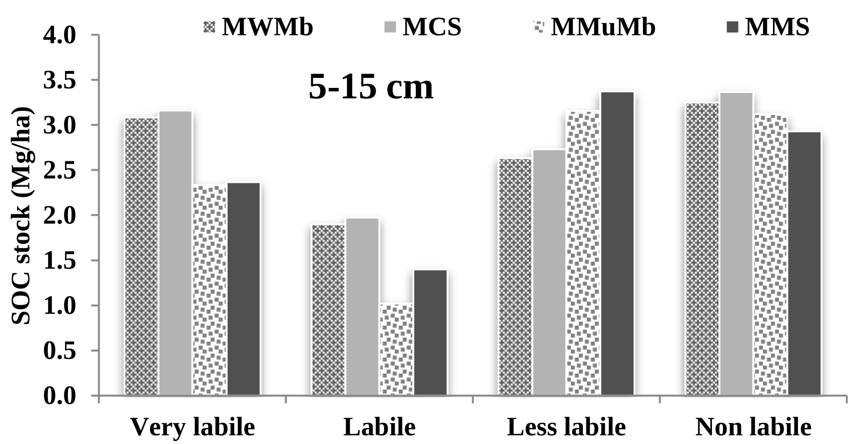
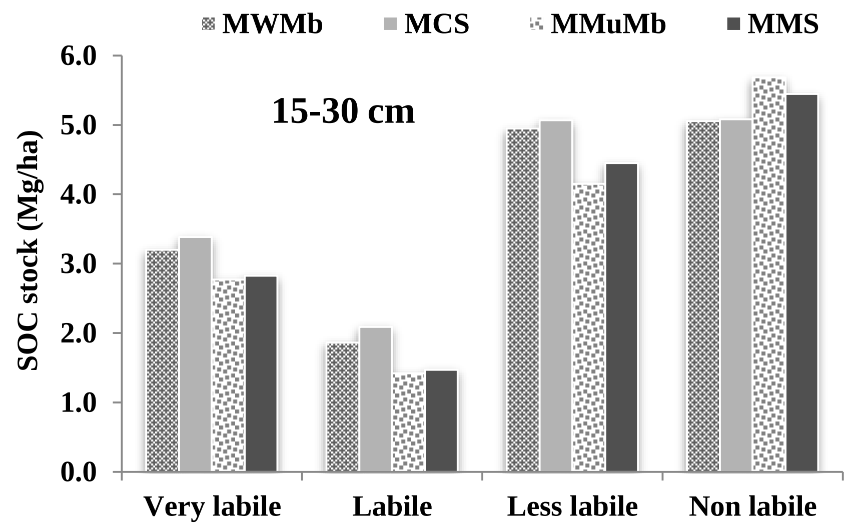
Effect diversified crop rotations on equivalent mass basis stock of SOC pools in different soil layers







Source: Parihar et al (ICAR-IARI/IIMR-CIMMYT collaboration)

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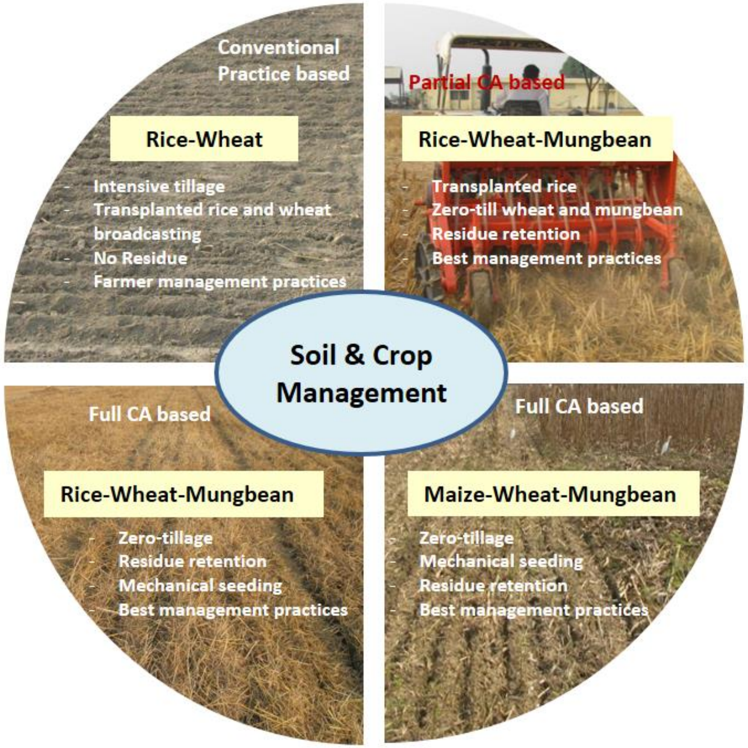
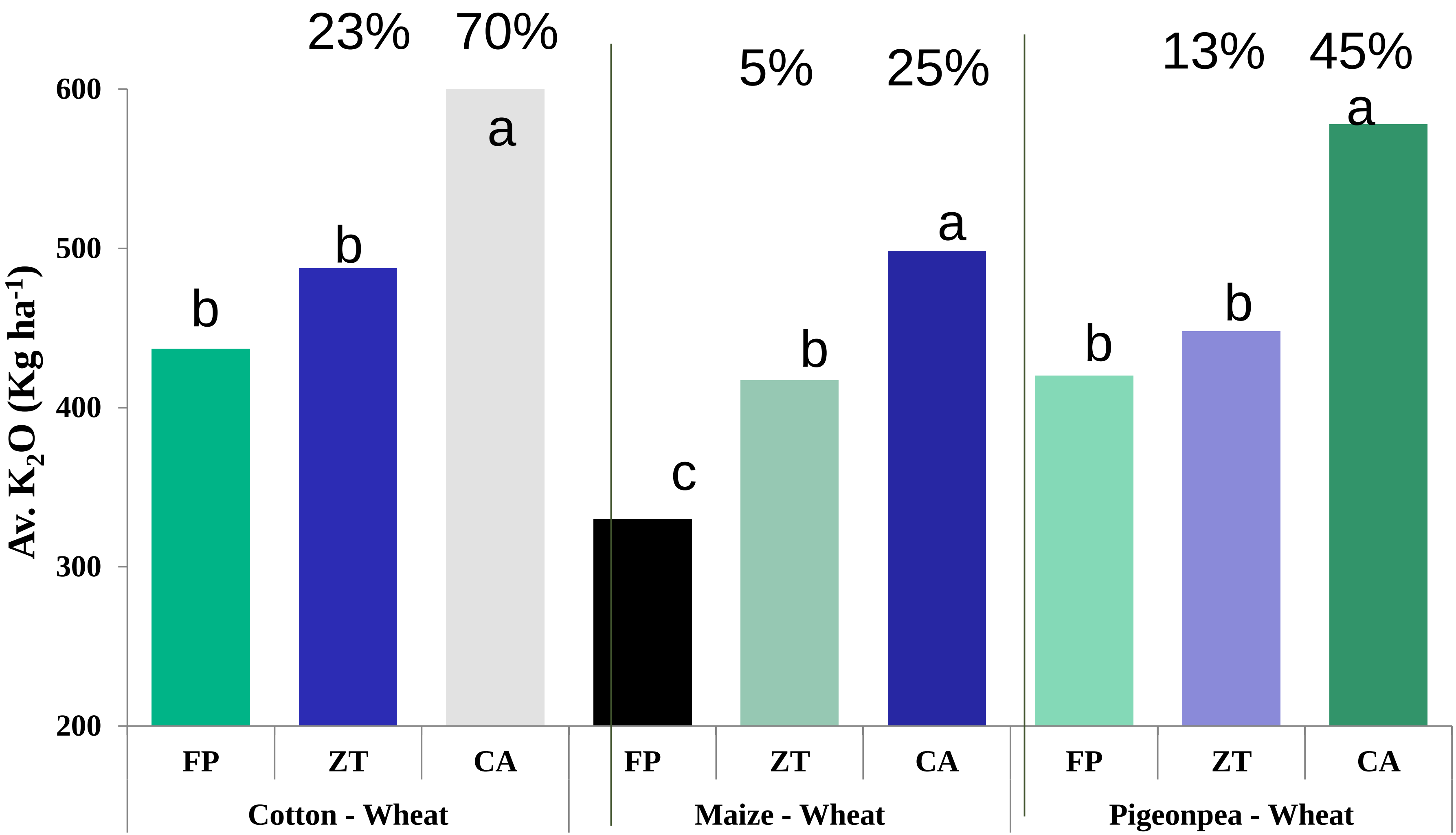
Changes in Nutrient Content in surface soil (0-15 cm) after 6 years of CA



Scenario	SOC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	pH	SQI
1	0.49	186.9	28.1	164.5	7.68	0.30
2	0.68	224.8	21.3	173.6	7.37	1.00
3	0.89	301.1	39.5	224.6	7.55	1.79
4	0.82	250.0	34.5	268.8	7.56	1.51
	(0.45)	(131.0)	(12.6)	(130.0)	(8.20)	

Av. Potassium under different Management Scenarios in Wheat based Cropping Systems



Initial: 396 kg ha^{-1}

Slide by YS Saharawat et al

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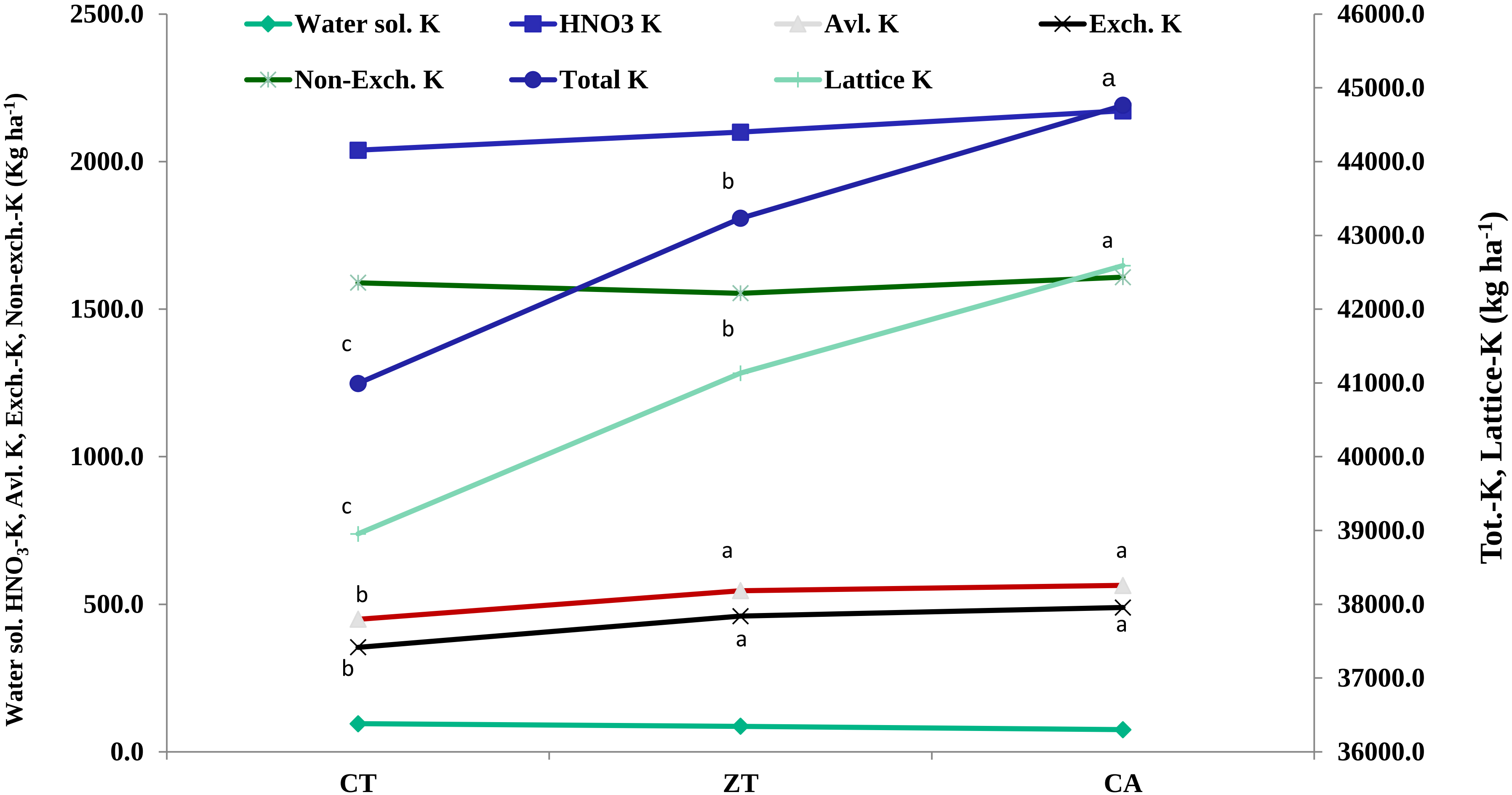
K Fractions under different Management Scenarios in Rice-Wheat System



Slide by YS Saharawat et al

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Effect of CA practices on Soil microbial biomasses

Microbial biomasses	CA based rice–wheat-mungbean	Integration of mungbean	MW verses RW
MBC	117%	66%	48%
MBN	171%	142%	73%

Biologically active fractions -sensitive indicators, predict direction and rate of change of soil quality earlier and better

Applied Soil Ecology, Geoderma

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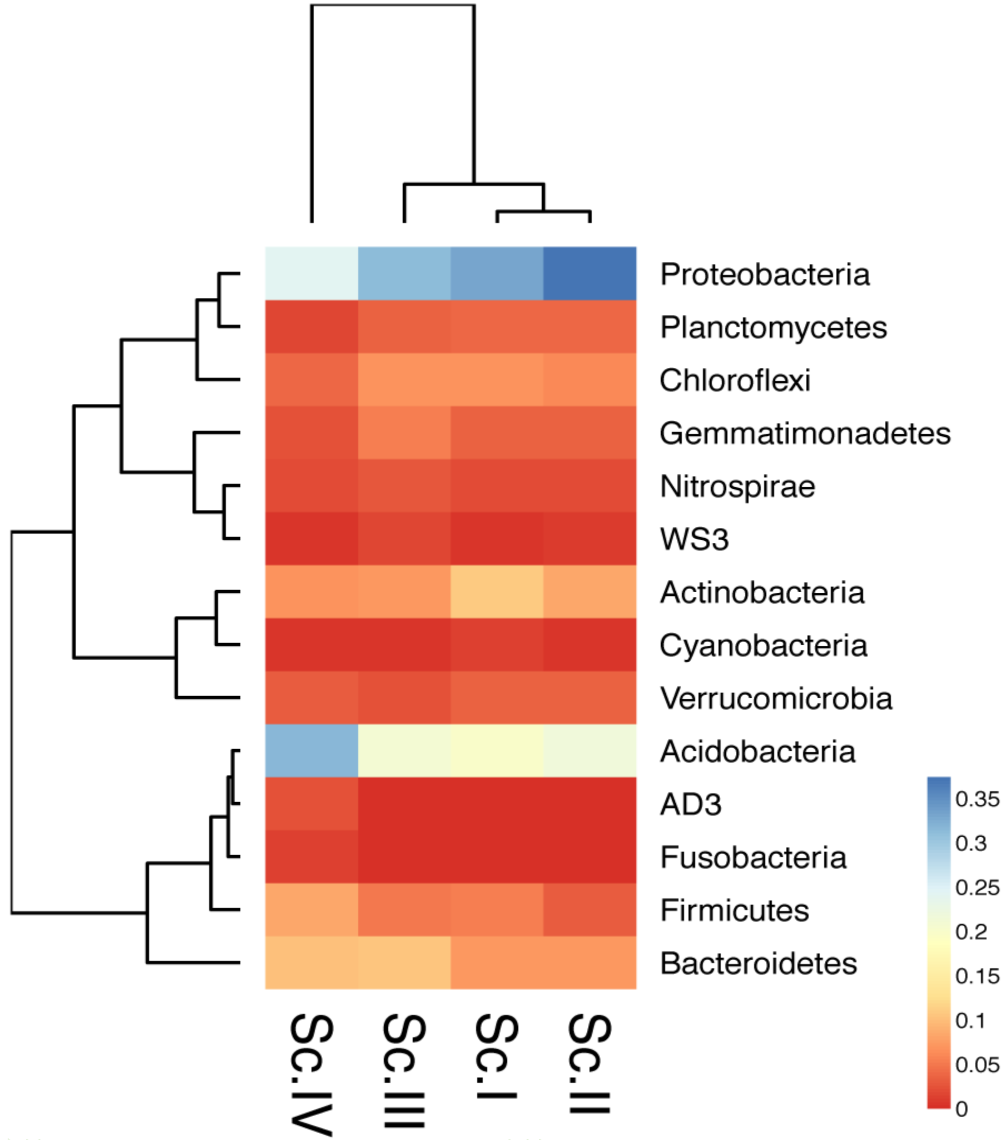
Metagenomic study of soil bacterial communities

Heat map is showing distribution of dominating phyla in scenarios

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



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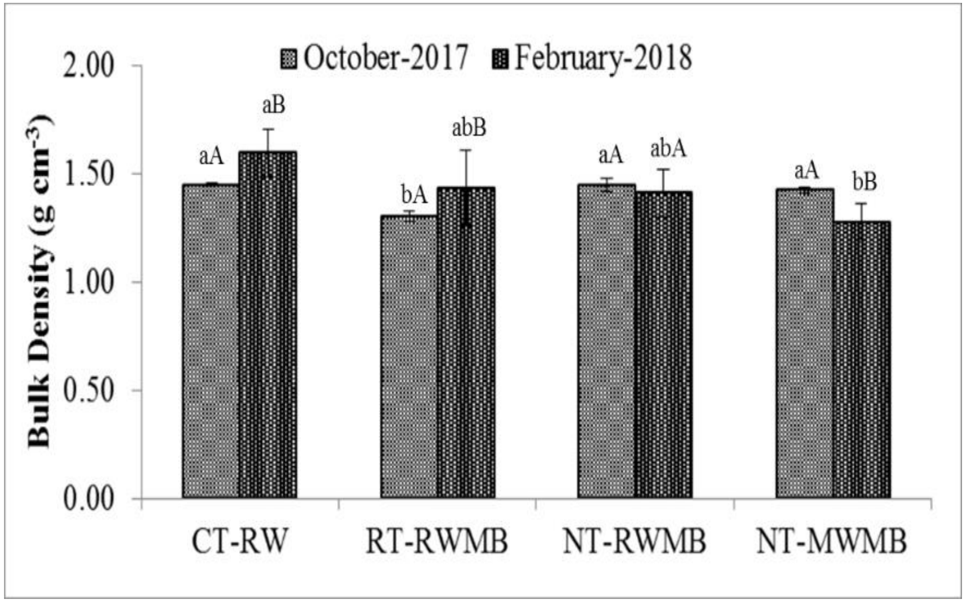
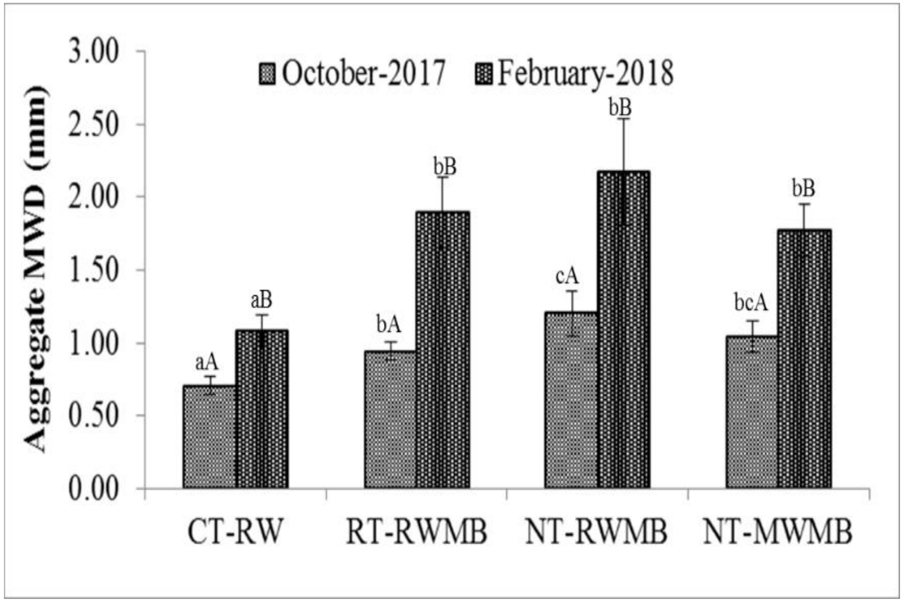
Temporal changes in bulk density and aggregate mean weight diameter (MWD) under different contrasting tillage and cropping systems management practices in a long-term research





Patra et al (2018), Soil & Tillage Research, submitted
UNU-CIMMYT-ICAR-CSSRI Joint research

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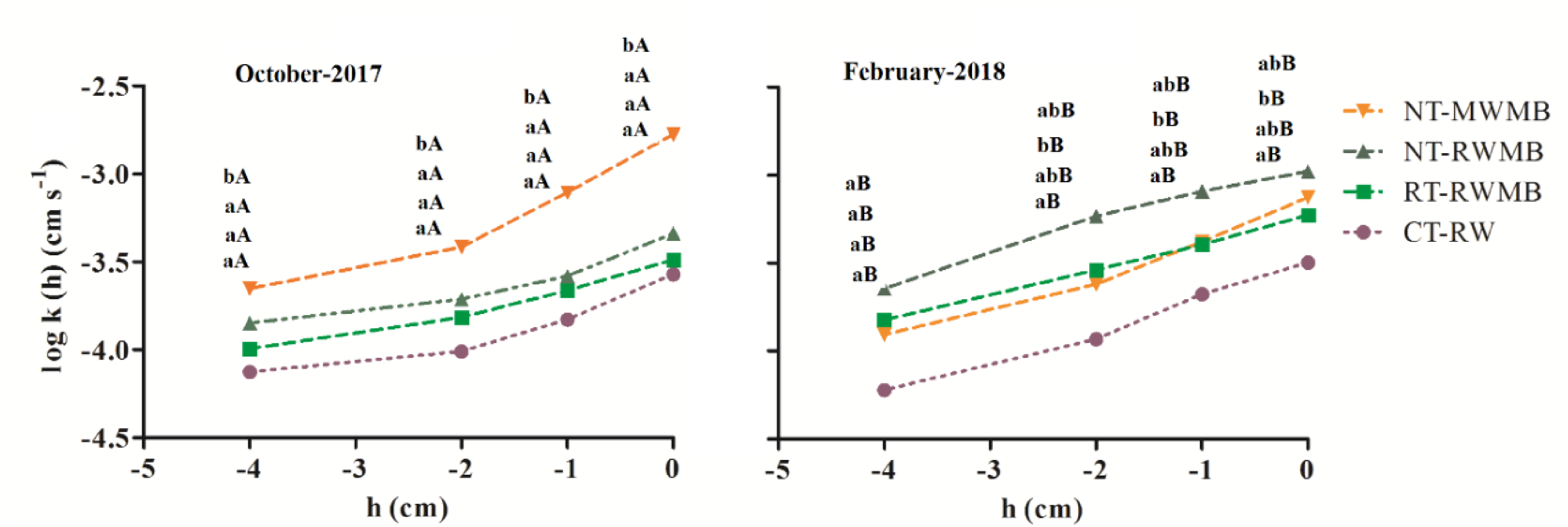
Near-saturated hydraulic conductivity k(h) as a function of the supply pressure head, h (cm)



- **Transition from maize to wheat in the CA based crop sequence reduced k(h) values by about 55-40 % at various pressure heads.**
- **In contrast, transition from rice to wheat in rice-based no till CA increased k(h) values by 129, 164, 124 and 24 % in the same pressure head ranges.**

Patra et al (2018), Soil & Tillage Research, submitted
UNU-CIMMYT-ICAR-CSSRI Joint research

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Archives of Agronomy and Soil Science

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Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India

H.S. Jat, Ashim Datta, P.C. Sharma, Virender Kumar, A.K. Yadav, Madhu Choudhary, Vishu Choudhary, M.K. Gathala, D.K. Sharma, M.L. Jat, N.P.S. Yaduvanshi, Gurbachan Singh & A. McDonald

K Levels (kg/ha)	Conv RWMb	Partial CA-RWMb	CA-RWMb	CA-MWMb
60	5.00^{a}	5.25^{a}	5.01^{a}	5.35^{a}
30	4.52^{b}	5.10^{b}	5.06^{a}	5.40^{a}
0	4.36^{c}	4.46^{c}	4.50^{b}	5.05^{b}

Wheat (mean of two years, 2014-15 and 2015-16) at different N doses (kg ha^{-1}) and rice after 6 years of continuous rice-wheat system under CA and CT

Treatment	Grain yield of wheat (t ha^{-1})					Grain yield of rice (t ha^{-1})
	N rates (kg ha^{-1})					
	0	82.5	105	127.5	150	150
Conv. tillage	2.26	3.41	4.31	4.58	**4.81**	7.30
CA	3.54 (56.6%)	4.33 (27.0%)	**4.89** (13.5%)	5.11 (11.6%)	4.96 (3.1%)	7.90 (8.2%)

Source: Jat et al (2017)

Effect of method and time of N application in no-till wheat sown into rice residues

N applied (kg ha^{-1}) at			Grain yield (tha^{-1})	Recovery Efficiency of N (%)
At sowing	Before 1st irrigation	Before 2nd irrigation		
25D+35B	60	0	4.42	45.0
25D+35B	30	30	4.29	44.1
25D+65B	0	30	4.27	41.9
25D+95B-0	0	0	4.02	39.1
25D	48	48	4.79	56.7

Source: Yadvinder-Singh et al. (2015)

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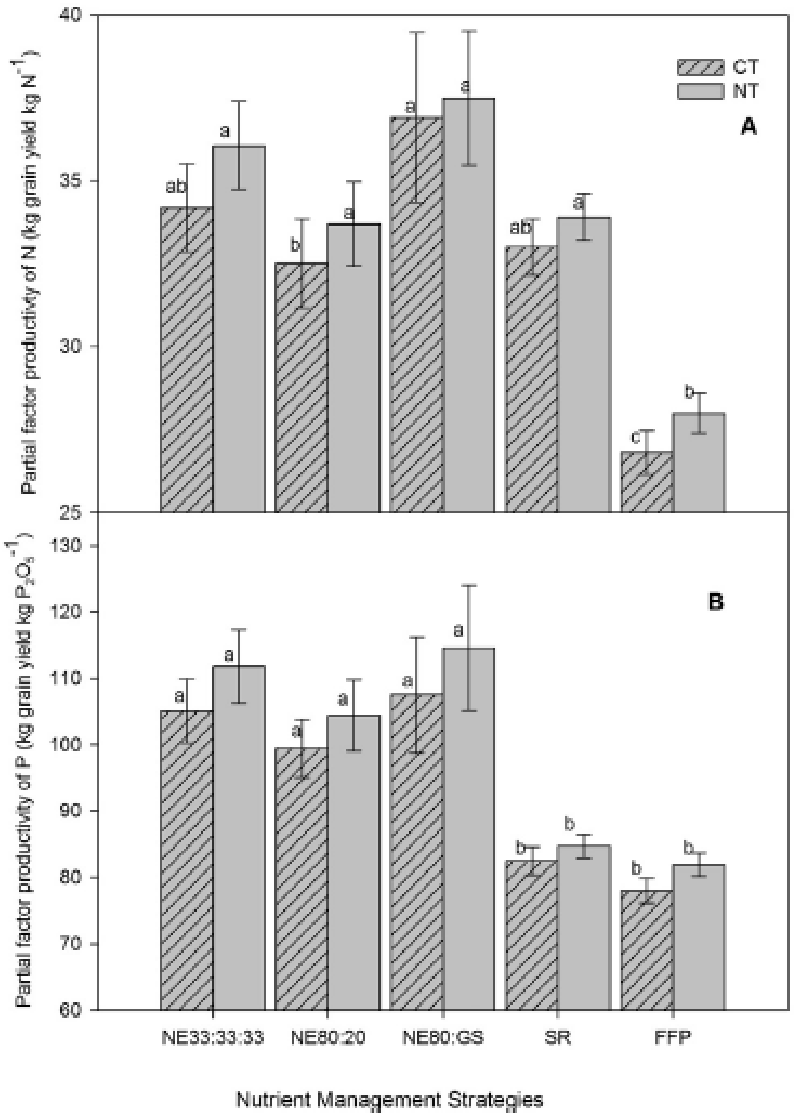
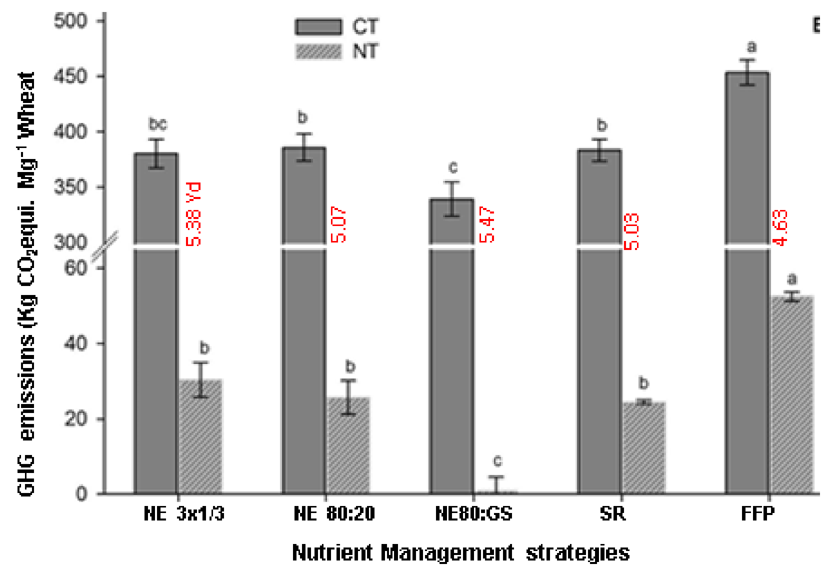
Layering Precision Nutrient Management in CA: NUE and GHG Emissions in Wheat





Sapkota et al 2014

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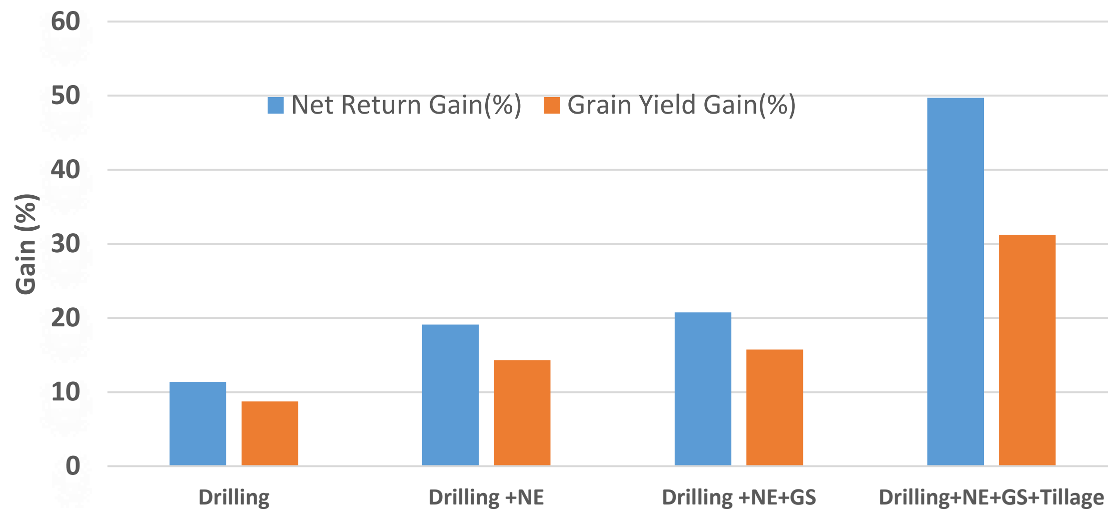
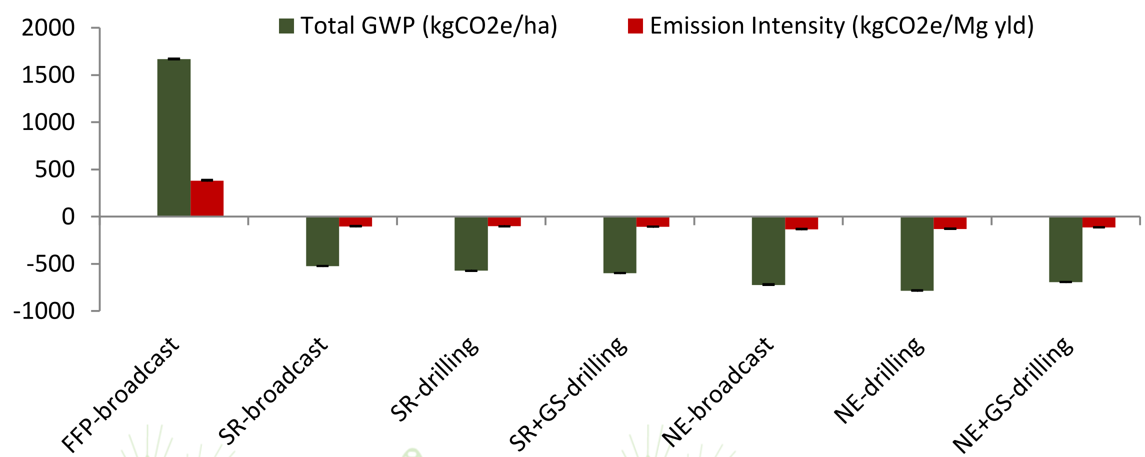
Smallholder Precision Nutrient Management holds the key: Example from *Eastern IGP*





Source: Jat et al (Forthcoming) (CIMMYT-BISA-CCAFS)

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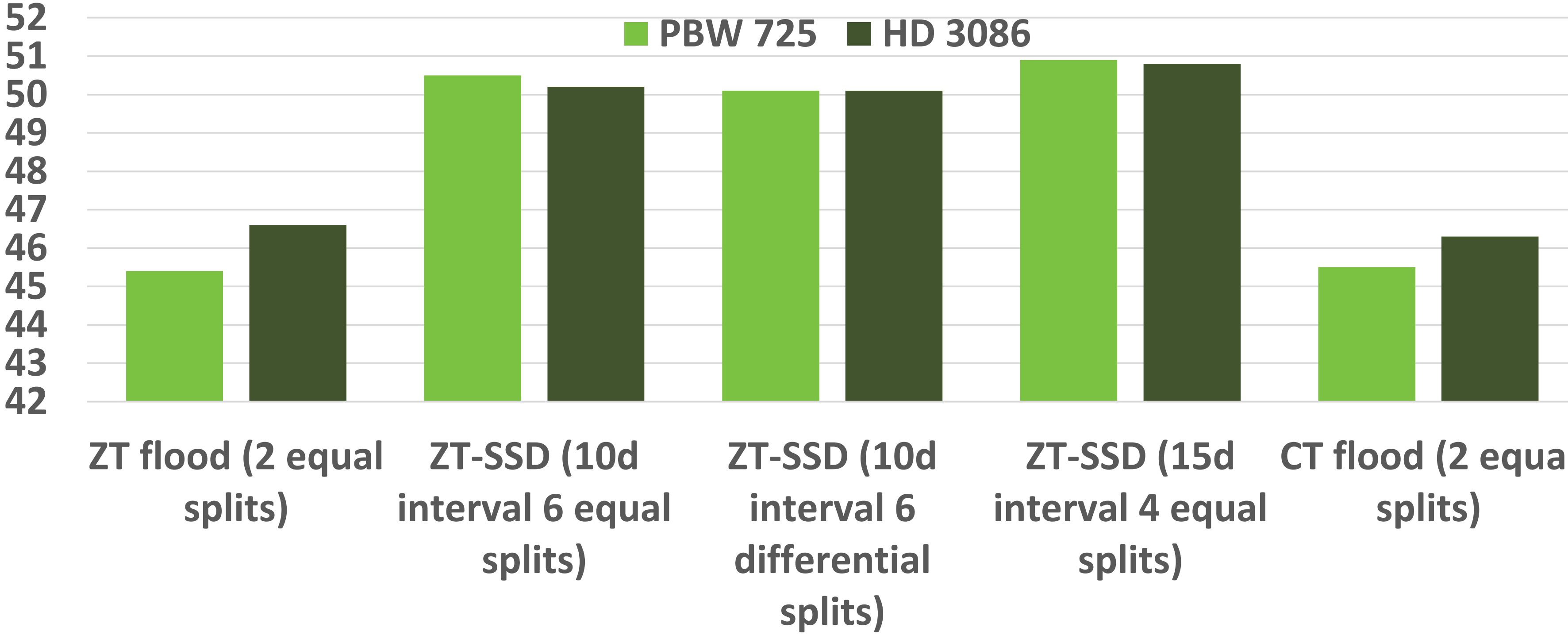
Portfolio: Layering precision water & nutrient management in CA based rice-wheat system

Treatment	Fertilizer N applied (kg ha^{-1})			PFP_N (kg grain kg^{-1} N applied)		
	Rice	Wheat	RWS	Rice	Wheat	RWS
ZTDSR-ZTW+R (SSD)	60	96	156	79.1ab	57.5a	65.8a
ZTDSR-ZTW+R (FI)	75	120	195	63.7c	43.2b	51.1b
CTRW-R-(FI)	60	120	180	75.9b	38.0c	50.7b

- **Layering sub Surface drip (SSD) irrigation system in CA based RW system produced (over conventional till rice-wheat)-**
  - ✓ **~1.0 t/ha/year higher RW yield**
  - ✓ **With ~70 cm less irrigation water**
  - ✓ **Double irrigation water productivity**
  - ✓ **38% increase in PFP-N**
  - ✓ **7.5 % lower environmental footprints**

Method and splits of N in Wheat (2017-18)

PFP_N (kg grain kg^{-1} N applied)



LSD: Management= 1.938; Geno= NS; M*G= NS

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Smallholder Precision Nutrient (& WATER) Management holds the key for intensification of maize systems- *Western IGP*

TCE & Irrigation (+ N application) method	Grain yield (t/ha)	Irrigation Water Use (mm)	WPi (kg/m^3)	AEN (kg/kg)
PB-SSD- (No-N)	7.33	201.0	3.65	-
PB-SSD- (60+60 kg N/ha)	13.41	254.9	5.26	36.5
PB-SSD- (90 + 90 kg N/ha)	14.34	260.2	5.51	38.9
PB-SSD- (120 + 120 kg N/ha)	14.58	255.8	5.70	30.2
PB-Furrow irrigation (120 + 120 kg N/ha)	14.15	609.1	2.32	28.4

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)	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

Lalit kr et al (CIMMYT-BISA-PAU Collaborative Research @ Ludhiana, Punjab, India)

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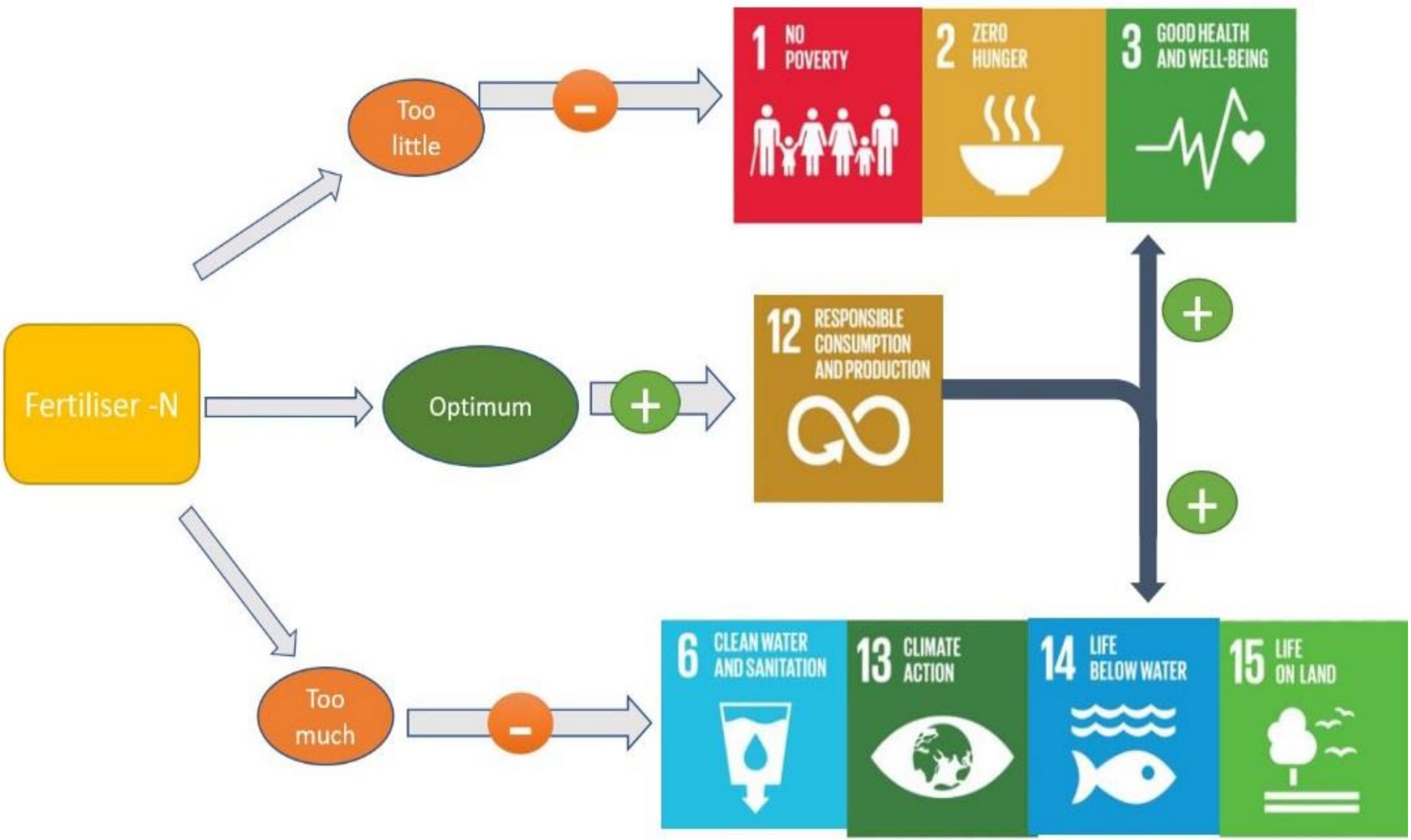
Nitrogen and Sustainable Development Goals



Source: Ladha, Stirling, Jat et al (2018) Advances in Agronomy-Under publication

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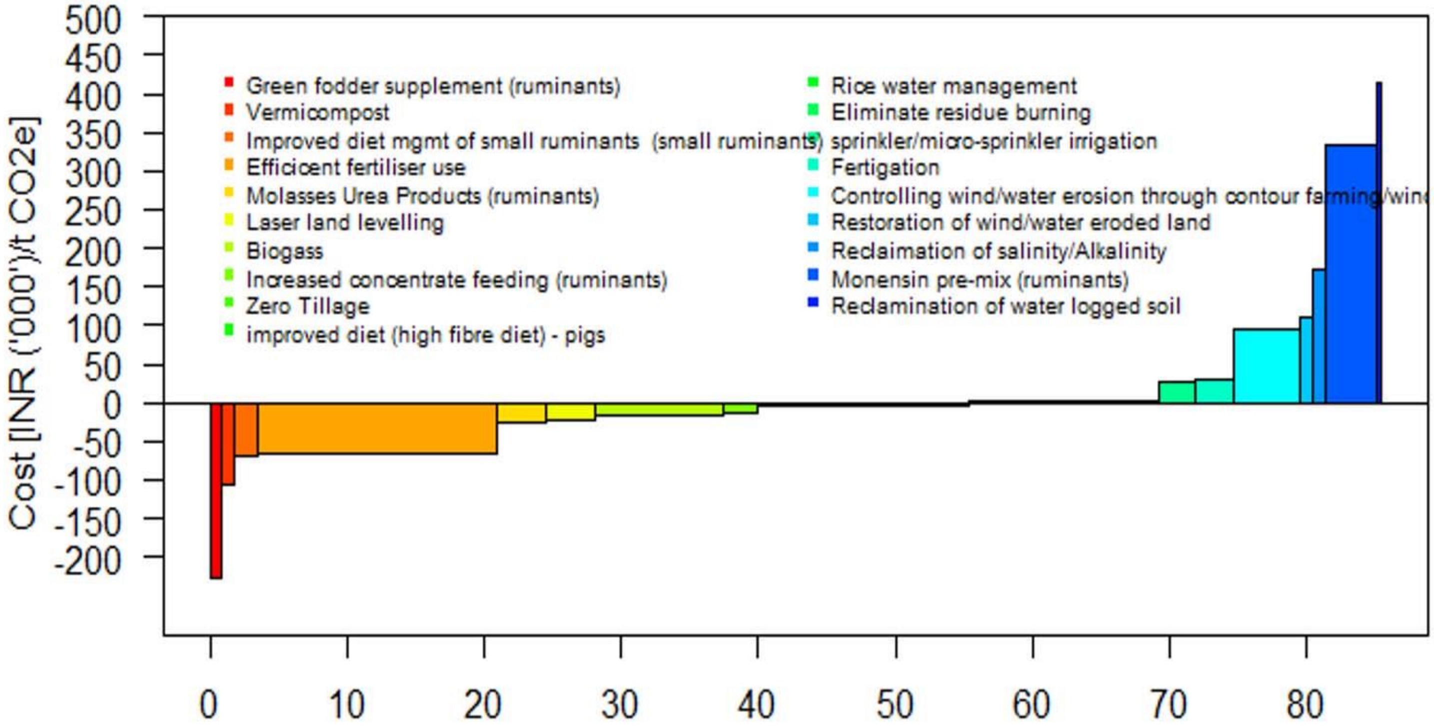
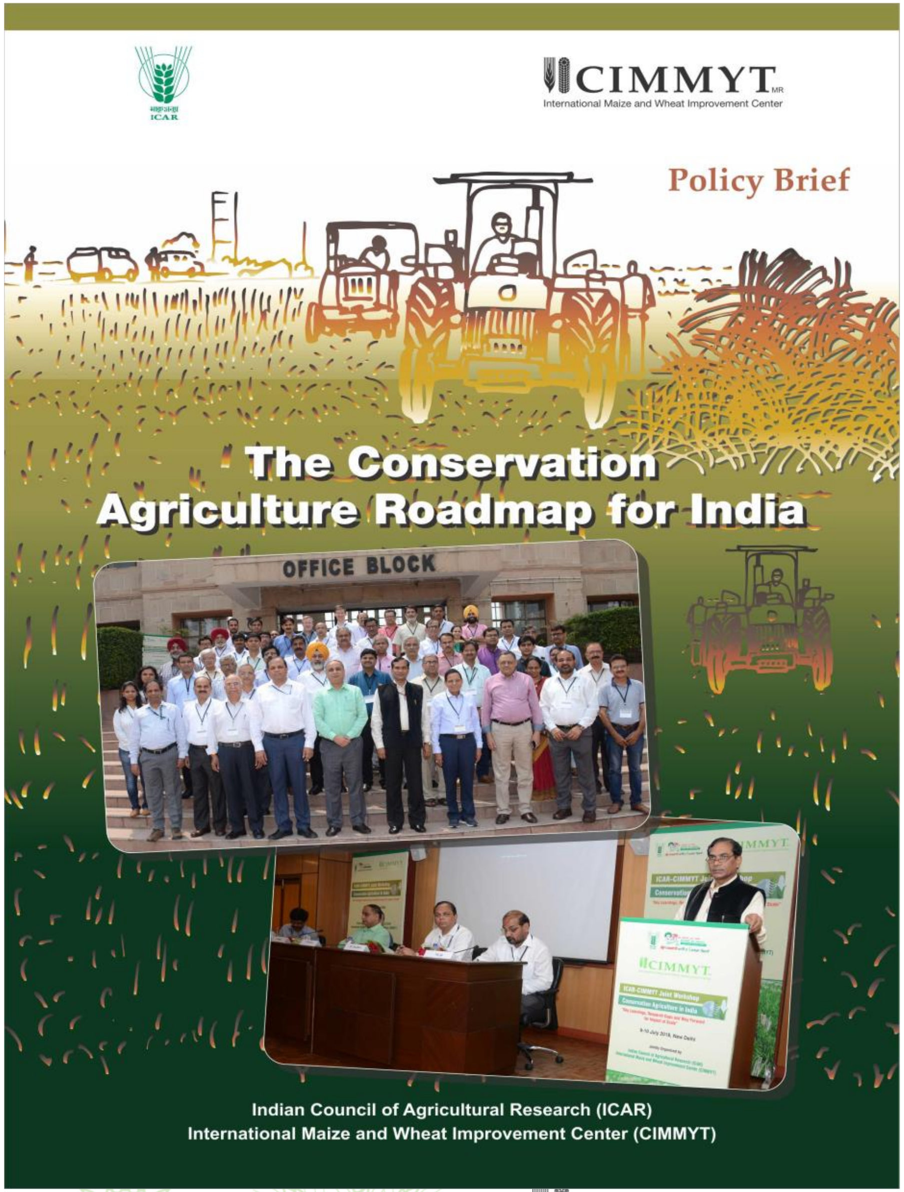
Evidence on Cost-effective opportunities for climate change mitigation in India



- All options are climate smart
- Technical Mitigation potential = 86 $MtCO_2e$/year
- 80% of mitigation potential achieved via cost saving options

Summary and Way forward

- CA is critical for addressing the multiple challenges of land degradation, climate change, input use efficiency and farm profits and achieving SDGs
- Nutrient dynamics are quite different under CA compared to intensive tillage based systems and warrants a new strategy for efficient use and management of nutrients
- In-depth understanding of nutrient dynamics in soil under CA is critical for efficient management.
- Need strengthening basic, strategic as well as applied research on nutrient dynamics and management under CA



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Thank you for your interest!

Sincerely acknowledge the team, institutes and collaborators

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