Climate change and cotton production in India-impact analysis and adaptation strategies

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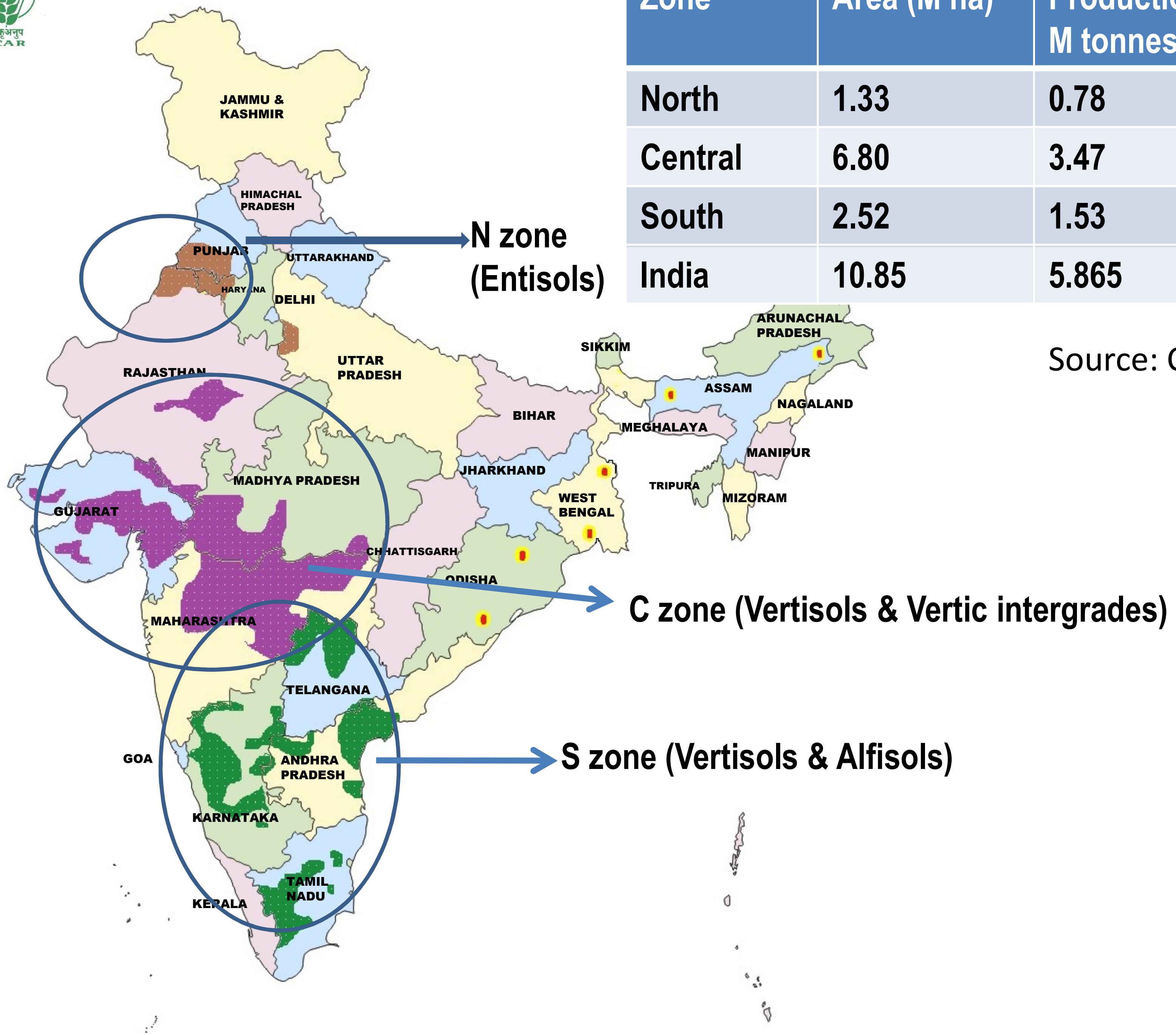
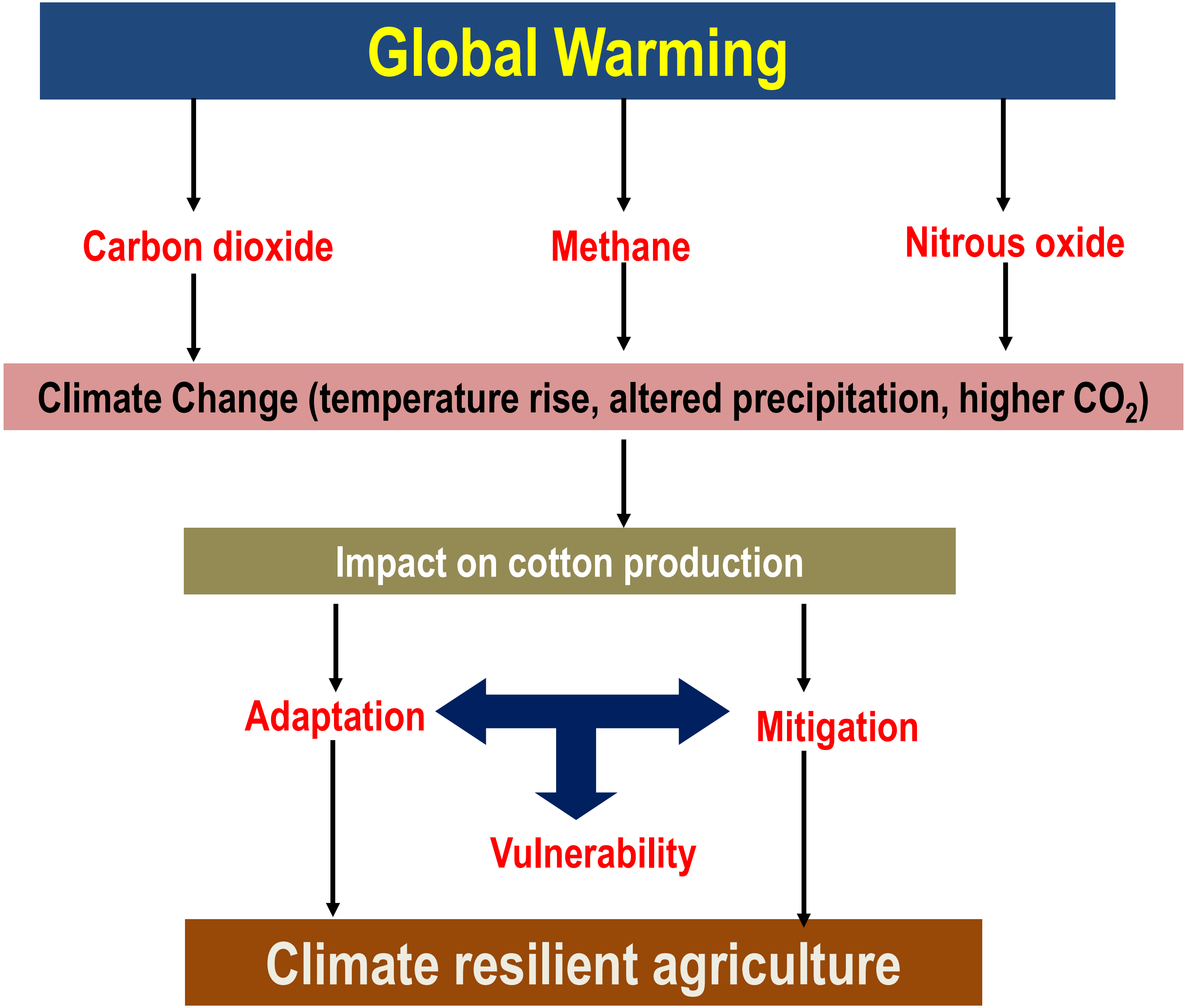
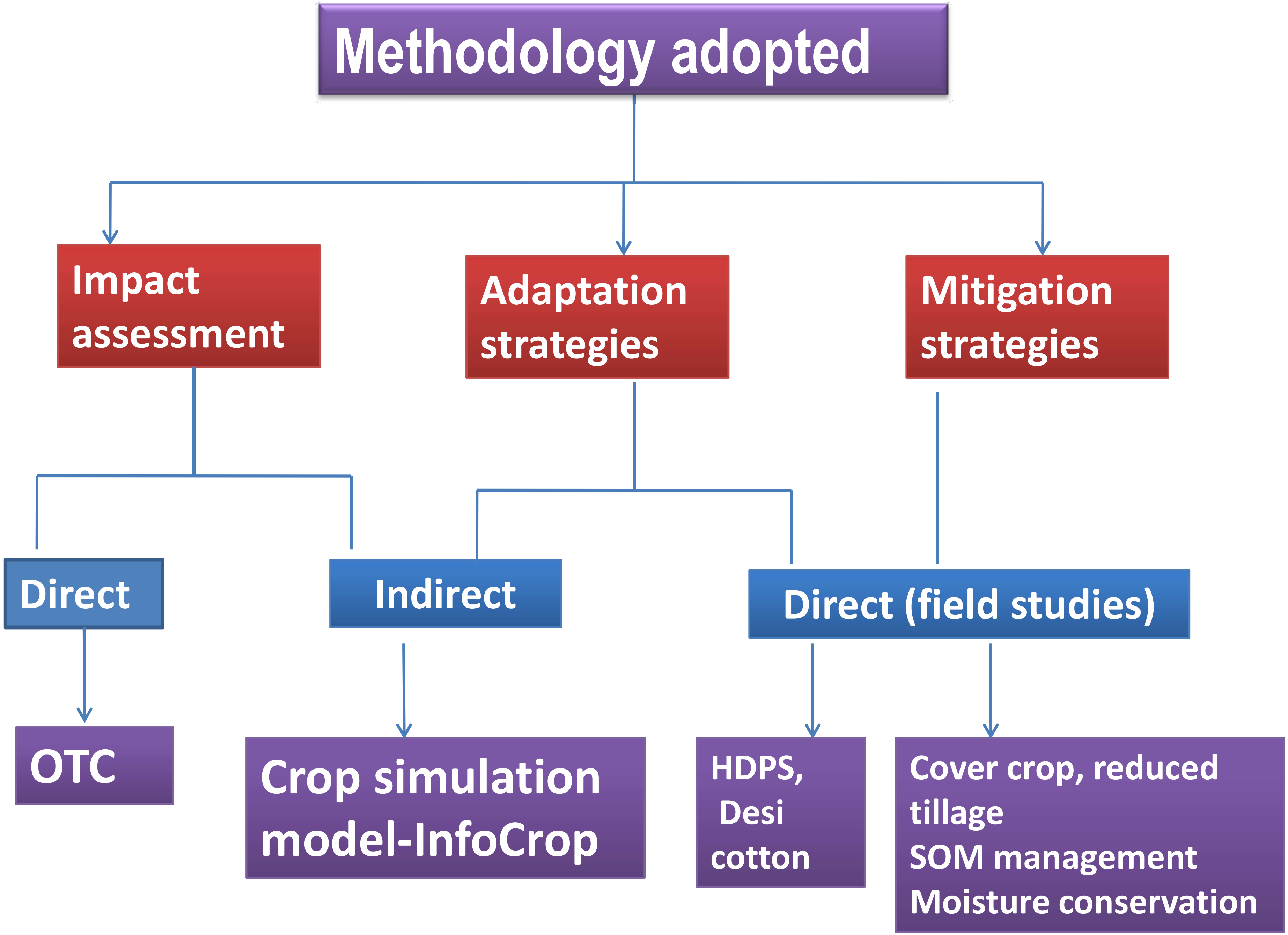
Zone	Area (M ha)	Production (M tonnes)	Yield (kg/ha)
North	1.33	0.78	586
Central	6.80	3.47	510
South	2.52	1.53	607
India	10.85	5.865	540

Source: CAB




Global Warming
Carbon dioxide
Methane
Nitrous oxide
Climate Change (temperature rise, altered precipitation, higher CO_2)
Impact on cotton production
Adaptation
Mitigation
Vulnerability
Climate resilient agriculture


Methodology adopted
Impact assessment
Adaptation strategies
Mitigation strategies
Direct
Indirect
Direct (field studies)
OTC
Crop simulation model-InfoCrop
HDPS, Desi cotton
Cover crop, reduced tillage
SOM management
Moisture conservation

OTC studies: Effect of temperature on cotton under elevated CO_2 atmosphere of 450±50 ppm

Experimental details

Genotype	Anjali (LRK 516)
CO_2 atmosphere	450±50 ppm (open top chambers)
Temperature	0.5˚C , 1.0˚C and 1.5˚C above ambient temperature
Layout	Completely Randomized Design
Date of sowing	03.07.2015

Physiological parameters (at 90 DAS)

Temperature above ambient (°C)	Photosynthetic rate (μ mol CO_2 $m^{-2}s^{-1}$)	Chlorophyll (SPAD value)	Transpiration Rate (μ mol H_2O $m^{-2}s^{-1}$)	Leaf Temp-erature (° C)
0.5	17.2	38.5	9.6	29.6
1.0	18.5	37.8	10.5	30.7
1.5	19.3	36.3	9.3	30.6
Ambient Control	15.6	35.6	7.4	28.3
CD @ 5%	1.89	2.15	0.42	0.4

Productivity attributes

Temperature above ambient (°C)	Boll wt (g/boll)	Yield (g/plant)	Harvest index	Dry matter (g/plant)
0.5	3.47	55.1	27.5	201.8
1.0	3.39	61.2	29.5	207.6
1.5	3.32	43.1	24.6	178.5
Ambient Control	3.51	46.8	26.5	177.1
CD @ 5%	0.15	2.96	0.71	14.1

Conclusion

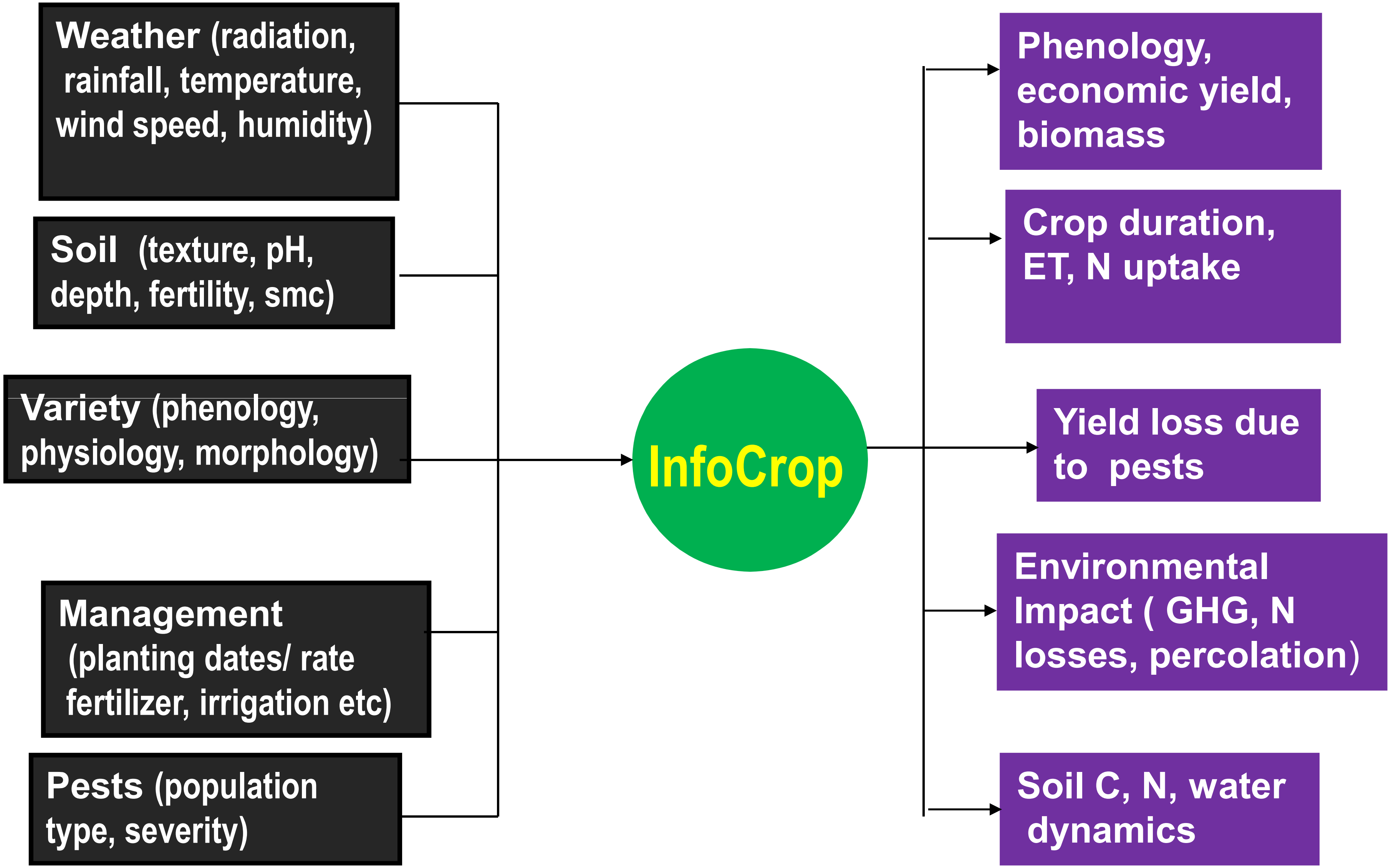
Elevated CO_2 (450 ppm) and temperature 1.0°C above ambient is conducive for cotton -morphological, physiological and productivity attributes. Beyond 1.0°C –detrimental effect.

Effect of elevated CO_2 and water stress on photosynthetic rate (µmol/m^2/s) in cotton

Treatment	Condition	Mean of 6 days after imposition of stress
Elevated CO_2 (650 ppm)	Unstressed	25.2
	Stressed	16.1
Ambient CO_2 (330 ppm)	Unstressed	21.4
	Stressed	15.5

Sankarnarayanan et al 2010

InfoCrop – INPUTS AND OUTPUTS



Simulation analysis using InfoCrop

Weather - gridded daily data 1°x1° - rainfall, min & max temperatures (IMD Pune-1969-1990). Solar radiation -Hargreaves method

Soil: National Bureau of Soil Science and Land Use Planning, Nagpur, India and Harmonized Global Soil Profile Dataset, Batjes, 2008). PTFs - soil hydraulic characteristic coefficients.

Varietal coefficients -based on field studies for medium and short duration cotton

Management: Analysis rainfed timely sown for C and S zone and summer sown irrigated N zone. Nitrogen as urea @100 kg N.ha^{-1} for irrigated and @80 kg N.ha^{-1} for rainfed.

Irrigation- whenever soil moisture reached 60% of field capacity.

Limited understanding of crop-pest interaction in future climates, assumed - crop was maintained pest/diseases free to quantify direct impacts of climate change (possible limitation).

Impact analysis:

1. **Estimation of Baseline Yield**: Yields of all the 22 years (1969-1990), simulated using above soil and weather data. District-wise baseline yield was obtained as sum of the weighted yield from each grid fraction in district. The simulated yield output was calibrated to district yield (district-wise mean yield of 2000-2005 period; DES, 2012) to get 'baseline yields calibrated to 2000-05 period'.
2. ***Simulating yields in future scenarios:*** temperature (min & max and rainfall data from MIROC-HR (Model for Interdisciplinary Research on Climate-High Resolution) 2020, 2050 and 2080 scenarios; the PRECIS (Providing REgional Climates for Impacts Studies) scenarios were used for analysis. 'Delta method' –used to overcome variation between observed weather and climate model outputs for baseline period (Olesen et al., 2007; Naresh Kumar et al., 2011).

- Projected CO_2 levels for respective scenario [**2020**-410 (B1), 418 (A1b); **2050**-482 (B1), 522 (A1b); **2080-** 530 (B1), 552 (B2), 639 (A2 and A1b)] was also included in model for simulations.
- The district-wise yields in future climates were calculated like 'baseline yields calibrated to 2000-05 period'.
- **Impact of climate change on mean yield of 22 years is expressed as percentage change from baseline mean yields.**

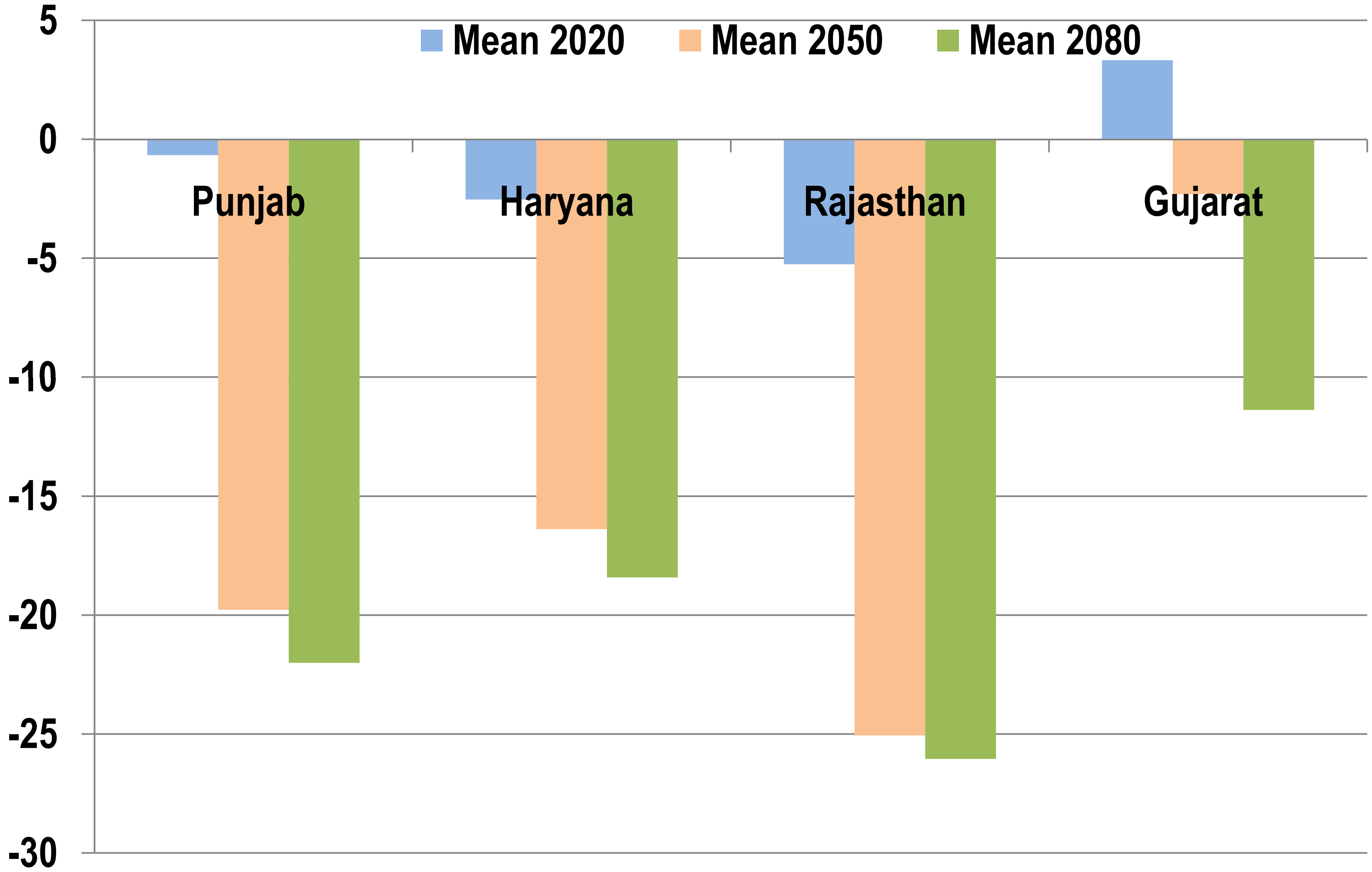
Simulating adaptation gains in future scenarios

Several low cost and easy-to-adopt options were tested independently or in combination

- ✓ Change in sowing date (early sowing)
- ✓ Switch over to short duration variety (150 days)
- ✓ Increase the seed rate
- ✓ Integrated nutrient application
- ✓ Split application of N (3 splits)

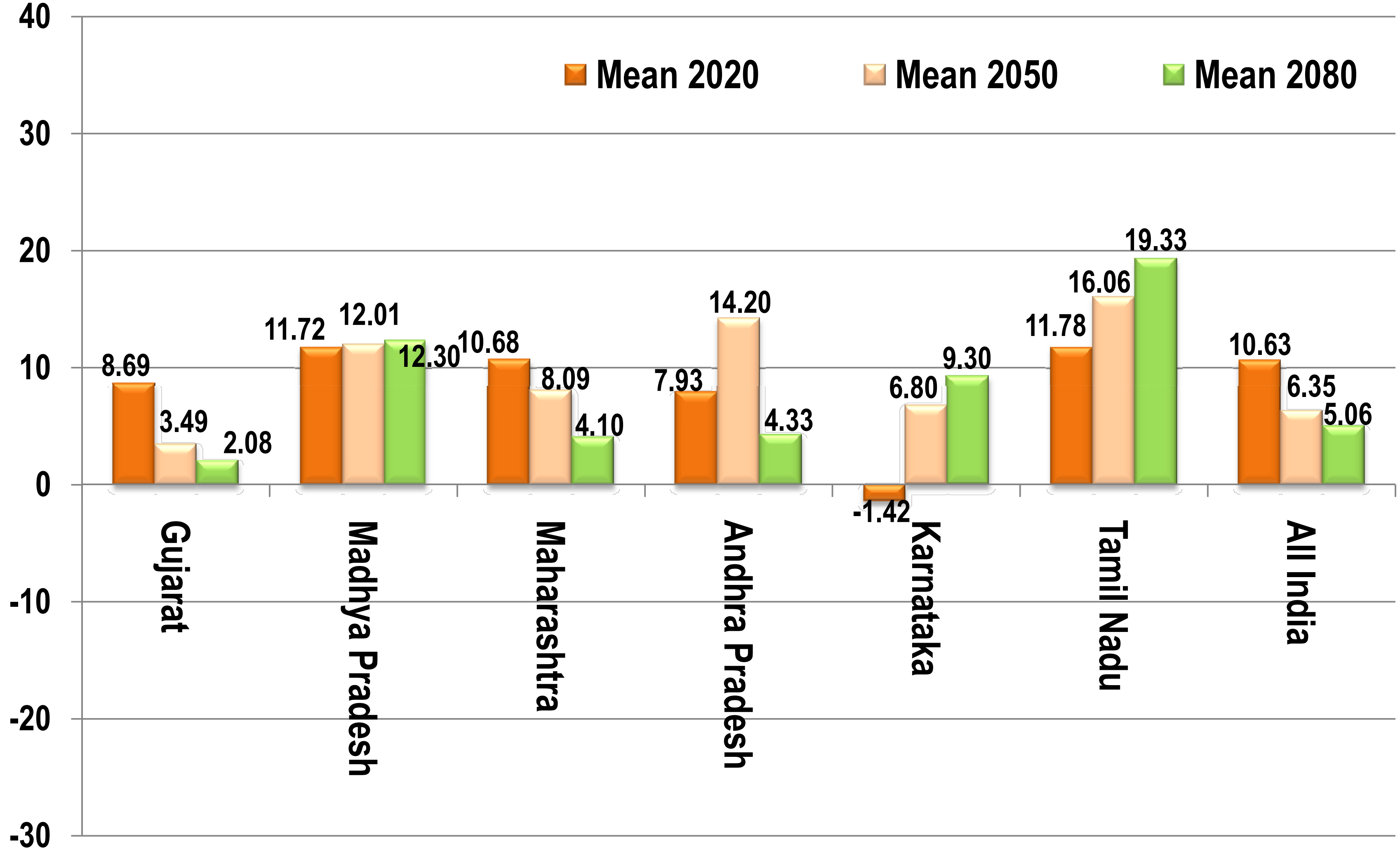
Combination which gave highest yield in each grid was taken as best suitable adaptation option. **The net change in mean yield of all 22 years was expressed as relative difference from mean baseline yield.**

Impact of future climate scenarios on productivity of irrigated cotton in North India and Gujarat (% change over baseline yield)



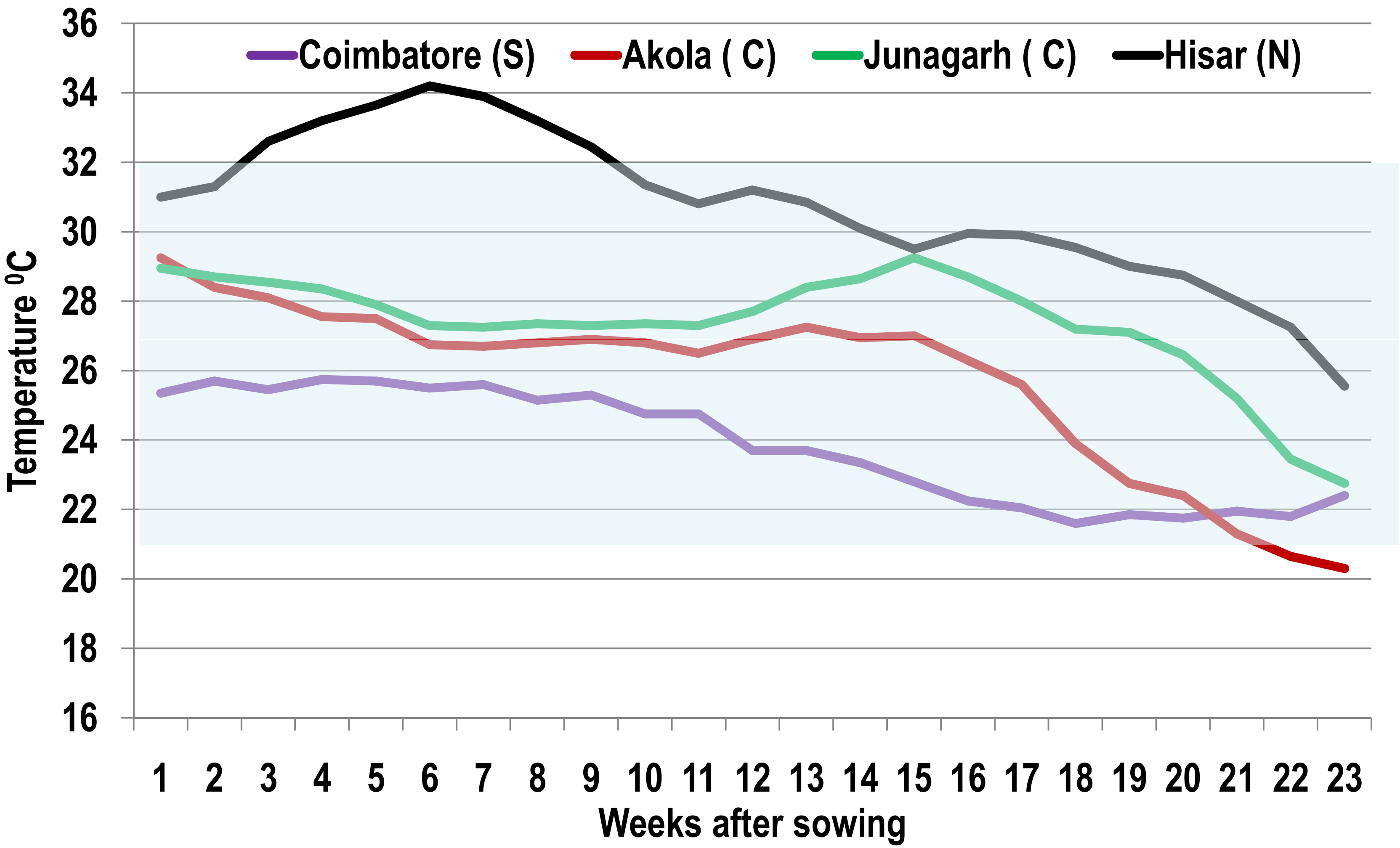
Increased temperature and reduced rainfall may decrease yield in North Zone

Impact of future climate scenarios on the productivity of rainfed cotton in India (% change over baseline yield)

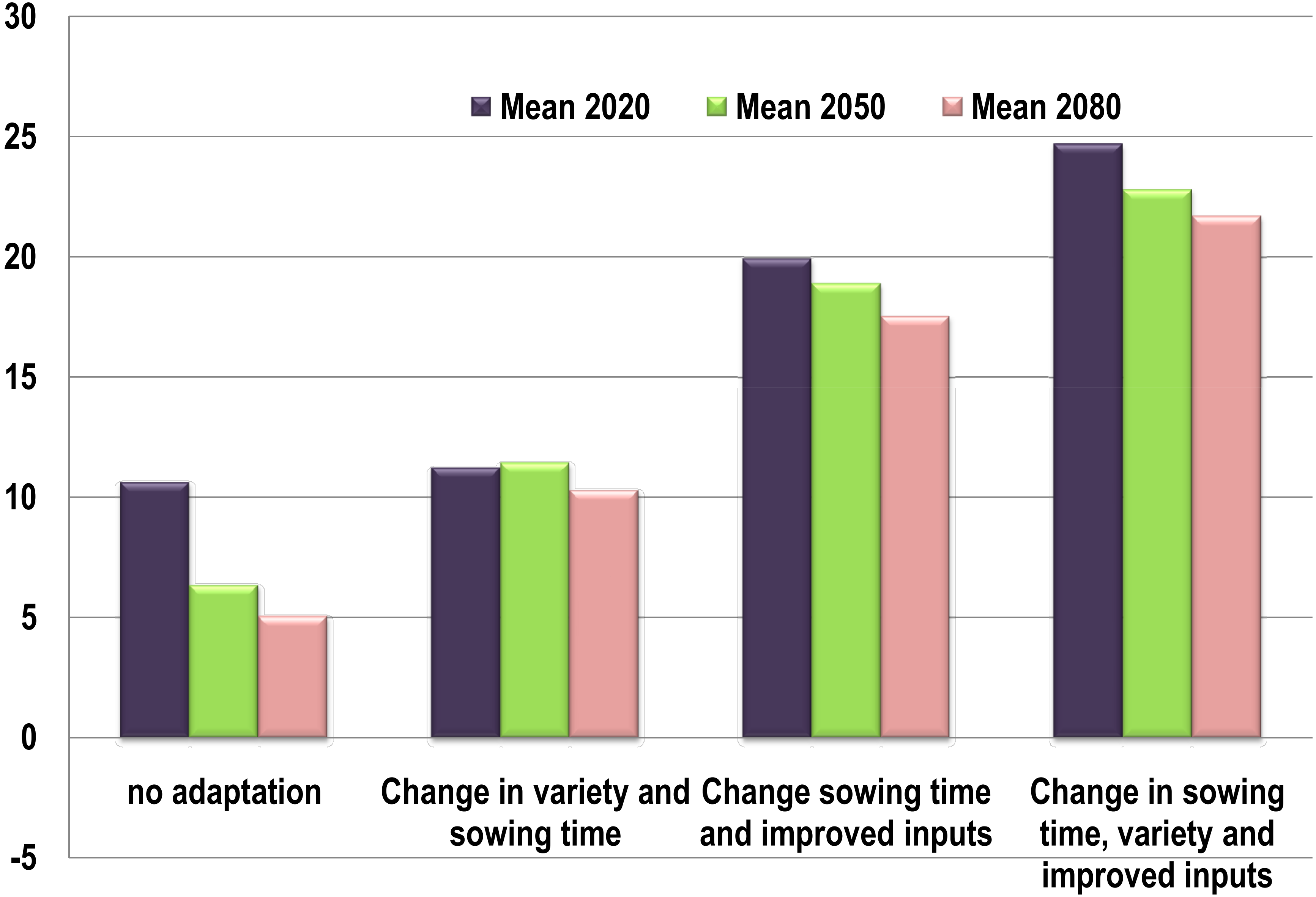


Rainfed yields in C and S Zone - increase slightly - compensatory effect of high CO_2 & increased rainfall

Mean temperature during growing seasons in different cotton zones of India



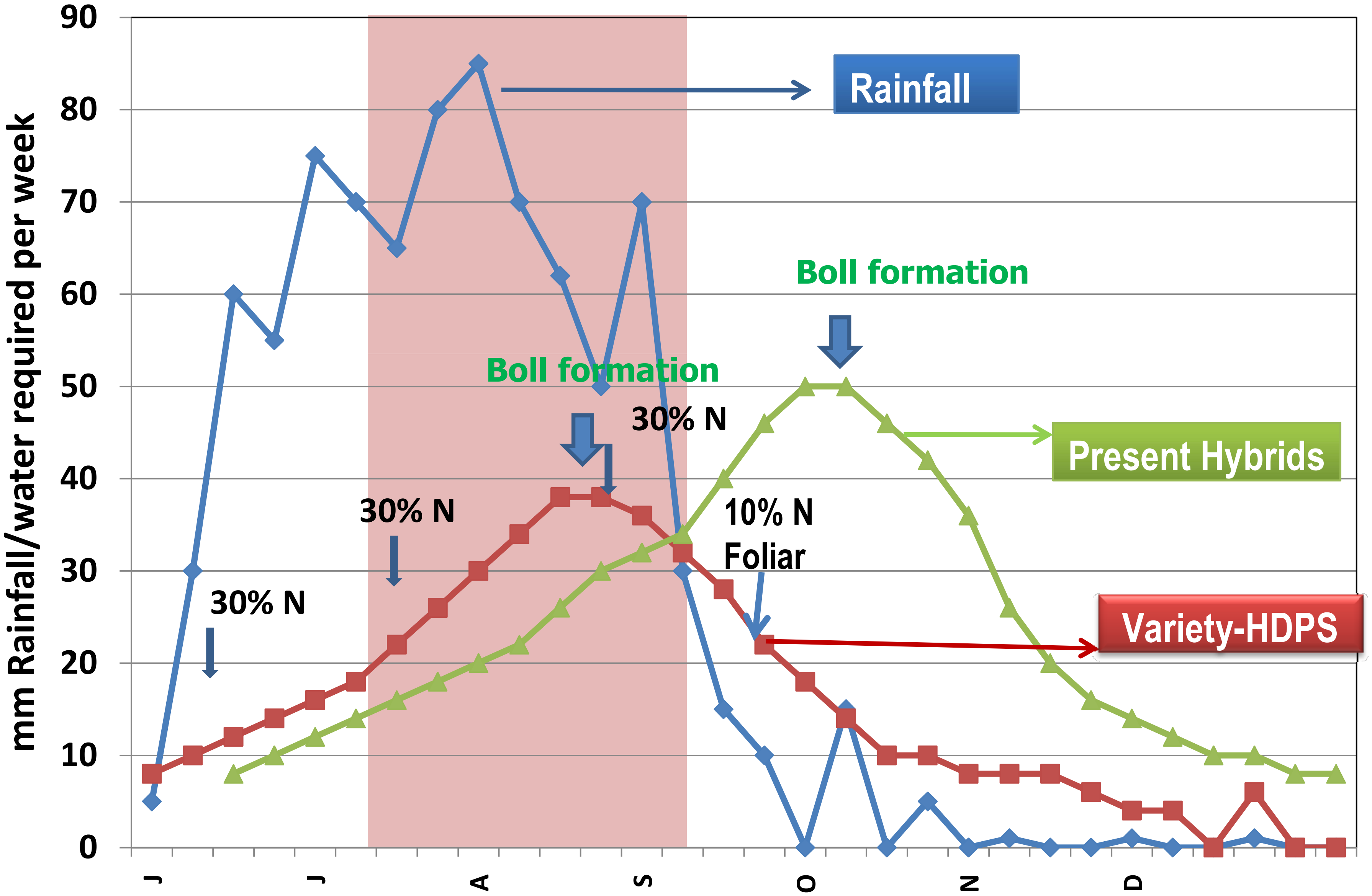
Quantification of adaptation gains (%) due to technological interventions in rained cotton



Adaptation Strategy: High Density Planting System (HDPS)- cotton

HDPS – semi-compact, early varieties - planted at population ranging from 111000 to 222000 plants/ha at 45 to 90 cm spacing between rows and 10 cm between plants

Central India –Water and N synchrony



Summary of research findings from HDPS trials

- Semi-compact genotypes – *G hirsutum*: PKV 081, Suraj, NH 615, NH 630, ADB 39, Anjali, F2383 and KC3. *G arboreum* -Phule dhanwantary, AKA 7, HD 123.
- Average yield improvement -30% over 60x30 cm spacing. Earliness -10 days.
- Current genotypes- density -1.5-2.0 lakh plants/ha - spacing 45x10 or 60x10 cm – rainfed, shallow to medium deep soils. Deep Soils : 75x10 cm. Significant -Soil type x genotype x row spacing interaction
- 25% more fertilizers over current recommendation for varieties. Nutrient uptake efficiency improved under HDPS. Nutrient utilization efficiency - not improved.
- Bullock/tractor drawn seed drills/planters – suitable. Tractor drawn inclined plate planter - most suitable.
- Growth regulator-mepiquat chloride in *G hirsutum* - decreased plant height ,Yield increase - not consistent in rainfed conditions. Yield increased in tall varieties, deep soils , irrigated conditions.
- No increase in pests and diseases under HDPS. However, being non Bt varieties, a separate window based IRM strategy was recommended.

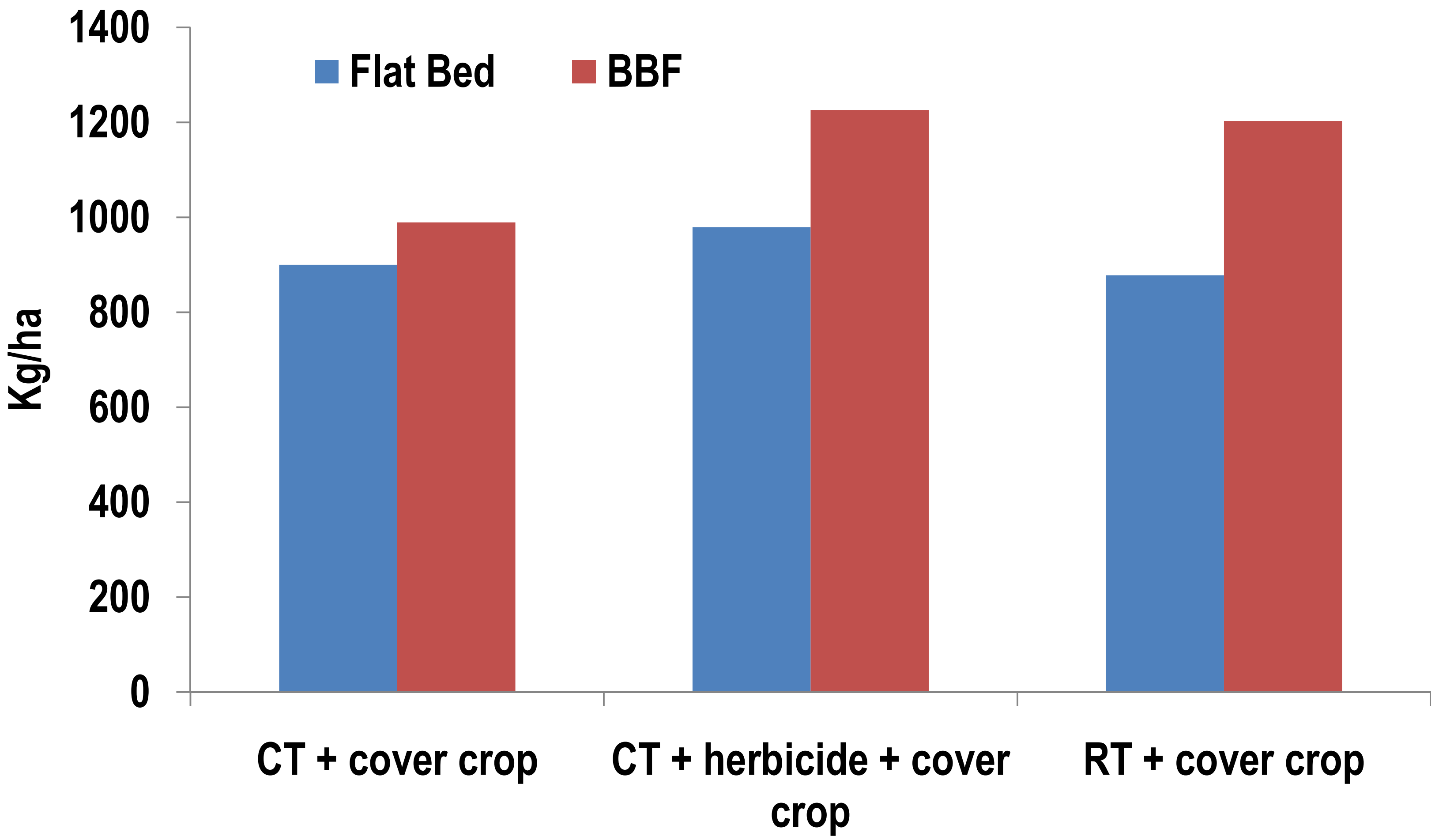
Adaptation Strategy: Long linted *G. arboreum* (*Desi* cotton) under HDPS- Yield (165 DAS) and fibre quality

Genotype	Lint yield in kg/ha (SE)	UHML (mm)	MIC ug/in	Strength (g/tex) - 3.2 mm gauge
PA-255	1177 (±31)	27.4	4.6	28.8
PA-08	1082 (±41)	28.3	4.7	28.7
PA-528	1240 (±61)	29.0	4.8	30.9
PA-760	1176 (±36)	29.9	4.4	29.1
PA 402	1089 (±8)	27.4	4.7	28.4
TKA-9102/3	977 (±48)	29.7	4.5	30.2
DLSA-17	1138 (±13)	29.5	4.6	29.6
PA - 740	1312 (±54)	28.3	4.7	31.1
PA -812	1222 (±71)	32.3	4.4	30.7
PA - 785	1248 (±35)	29.8	4.4	30.6
Ajeet 155 BG II	928 (±17)	29.1	4.0	28.4

Mitigation strategy: Cover crop and mulch – weed management and water conservation

- **Broadcast sun hemp in between cotton rows (15 days after cotton emergence). Turn down after 30-35 days**
- **Brown mulch effective in controlling weeds and also conserve soil moisture**

Comparison of BBF and flat bed system



- Cover crop mulched and BBF technique had higher soil moisture content
- Yield increase with BBF was significant

Trial to be continued ....

HDPS and cover crops-Mitigation strategy

G. arboreum **cotton variety in HDPS**

HDPS with a legume cover crop

- ✓ High density planting and cover crop/ inter crop increases biomass production almost by 60-70%.
- ✓ Almost 1.1 tonnes of carbon per hectare is sequestered and stored in biomass in high density planting system.

Soil organic matter management - reduce natural degradation of SAT Vertisols

Cotton growing Vertisols of SAT - contain both pedogenic $CaCO_3$ (PC) and non-pedogenic $CaCO_3$ (NPC). Dissolution of NPCs in alkaline environment provides Ca^{++} that are precipitated as PCs. NPCs are coarse in texture whereas PC are fine in texture.

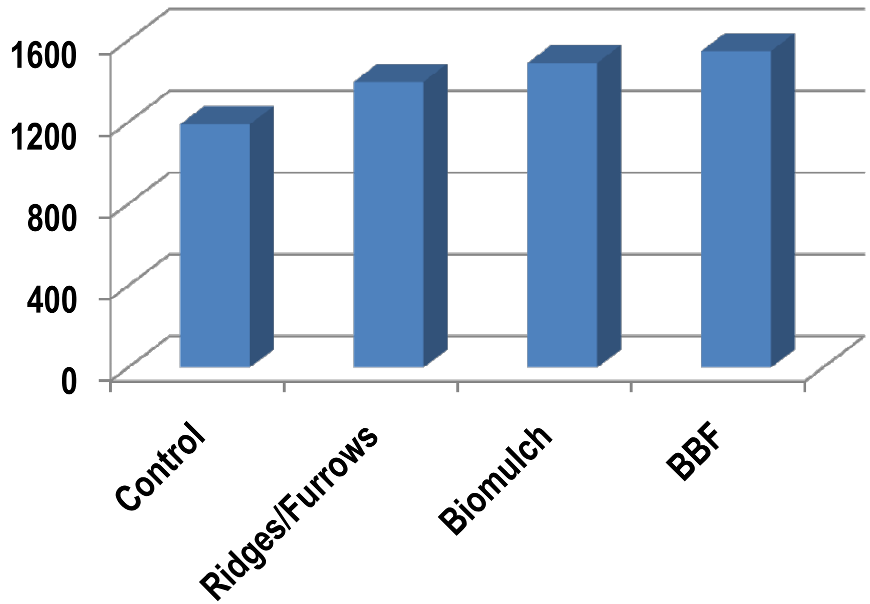
Subsoil sodicity induced by the presence of PC decreases hydraulic conductivity (< 10mm/h) and impairs drainage.

Solution:

- The return of crop residues, application of FYM, green manure, intercropping, soil moisture conservation and balanced fertilizers can increase SOC content.
- Organic acids from SOC decomposition - decreases soil pH and dissolves $CaCO_3$ and releases Ca^{++} and improve soil aggregation/ floculation. This arrests natural degradation of Vertisols due to formation of PCs.

Soil moisture conservation techniques on rainfed *G. hirsutum* cotton (Suraj) –adaptation & mitigation strategy

Seed cotton yield (kg/ha)



Acknowledgement:

- NICRA project (ICAR) for funding the study
- ICAC for sponsorship for participation
- ICAR for permission
- Director ICAR-CICR for support
- Dr Mohamed A. M. NEGM and the local oraganizers

Thank you