Scalable Innovations of Climate Smart Agriculture

ML Jat

With contribution and support from may colleagues, partners & donors
Global Warming in South Asia: 800 Million at Risk

By SOMINI SENGUPTA and NADJA POPOVIC
JUNE 28, 2018

Moderate emissions scenario
South Asia warms about 1.6°C by 2050

High emissions scenario
South Asia warms about 2.2°C by 2050

Decrease in living standards:
NONE  LOW  MODERATE  HIGH  NO DATA
Agricultural Challenges

**Manmade**
- Monotonous cropping systems (e.g., rice-wheat)
- Out of place cropping systems
- Intensive tillage
- Residue burning
- Flood Irrigation
- Blanket nutrient use and broadcast application

**Nature made**
- Climate change induced weather risks
- Abiotic stresses - temperature (terminal heat, cold), monsoon variability, water stresses (dry spell, excess rains), salinity
- Biotic stresses - pest outbreak, weed, diseases etc

- Continued depletion of water
- Soil health deterioration
- GHGs/Global Warming
- Yield gaps & Low farmer’s profit

**Twin Challenge:** Enhancing Farmer’s income with sustaining natural resources under emerging climatic risks
Efficiency and Sustainability of Agricultural System Depends on Complex Interactions

- Physical resources (Land, water etc)
- Biological resources (Agro-biodiversity)
- Environmental resources
- Social Resources (human capital, economic, market etc)
- Management inputs/systems

Efficiency and Sustainability of Natural Resources
Technological (Innovations?) Advancements in Climate Smart Agriculture

• Have done very well in CSA technological advancements
• Primarily commodity centric, revolved around (Bio) physical parameters
• Lack of system’s approach (farmer has a system)
• Lacking social inclusivity in technology development
• Poor linkage in different elements of impact pathway (technology developers, providers, knowledge & capacity links and adopters)
• Area general adhoc recommendations
• Even the site-specific management prescriptions need farmer circumstance specificity element for its adoption
• Technology + Local adaption + Social inclusivity + Access + Feedback + Willingness to buy/pay = INNOVATION
Climate-Smart Agriculture

Consortium of Practices and Policies

Combines policies on:
- Adaptation
- Mitigation

Outputs:
- Productivity
- Returns
- Efficiency
- Emissions
- Resilience
## CSA Matrix of different technological innovations

<table>
<thead>
<tr>
<th>CSAPs</th>
<th>Adapt (3)</th>
<th>Mitig (3)</th>
<th>Yield/income (3)</th>
<th>Mat. Tech Dev (2)</th>
<th>Adop. dom (2)</th>
<th>Farmer accep (3)</th>
<th>Social &amp; gender impl (2)</th>
<th>Innovation strength (1)</th>
<th>Lever by R&amp;D inst. (1)</th>
<th>Policy backup (1)</th>
<th>Results with No weights (Maximum of 40 points)</th>
<th>Results with No weights as fraction of maximum attainable</th>
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</table>
CA based in Intensive Cereal Systems in NW India: Productivity, Profitability, Soil quality and Environmental footprints (8 yr average)

*In parenthesis= % change over conventional system

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Productivity (Mg ha(^{-1}))</th>
<th>Irrigation water (mm ha(^{-1}))</th>
<th>Energy requirement (MJ ha(^{-1}))</th>
<th>Net return (USD ha(^{-1}))</th>
<th>Organic carbon (%)</th>
<th>Total GWP (t CO(_2) eq ha(^{-1}))</th>
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<td>Conventional RW</td>
<td>12.40</td>
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<td>75225</td>
<td>1361</td>
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<td>CA based RW</td>
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<td>1629</td>
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<td>(-27)</td>
<td>(-23)</td>
<td>(20)</td>
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<td>CA based MW</td>
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<td>2122</td>
<td>0.84</td>
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<tr>
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<td>(14)</td>
<td>(-71)</td>
<td>(-48)</td>
<td>(56)</td>
<td>(87)</td>
<td>(-29)</td>
</tr>
</tbody>
</table>

*ICAR-CSSRI-CIMMYT Collaborative Research*
Meta-data analysis of CA research in major cereal based systems in South Asia: Yield response to different elements

Source: Jat et al (Forthcoming)
Meta-data analysis of CA in South Asia: Yield Gain/Loss in different soil types

Source: Jat et al (Forthcoming)
Meta-data analysis of CA in South Asia: Yield gain/loss in different crops

Source: Jat et al (Forthcoming)
Meta-Analysis of Alternate Rice Production Systems

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

Debashis Chakraborty, Jagdish Kumar Ladha, Dharamvir Singh Rana, Mangi Lal Jat, Mahesh Kumar Gathala, Sudhir Yadav, Adusumilli Narayana Rao, Mugdoli S. Ramesha & Anitha Raman

Direct Seeded Rice

Vaishali, Bihar (2015) - Drought Year
CA in Wheat Systems Adapting to Terminal Heat

Source: Jat et al (2009)
Performance of 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

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

Jeetendra Prakash Aryan, Climate Economist\textsuperscript{a,b}, Tek Bahadur Sapkota, Mitigation Agronomist\textsuperscript{a}, Clare Maeve Stirling, Senior Agronomist\textsuperscript{b}, M.L. Jat, Senior Cropping Systems Agronomist\textsuperscript{b}, Hanuman S. Jat, Senior Agronomist\textsuperscript{a,b}, Munmun Rai, Senior Agronomist\textsuperscript{a}, Surabhi Mittal, Senior Agricultural Economist\textsuperscript{a}, Jhabar Mal Sutaliya, Senior Agronomist\textsuperscript{a}

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\textsuperscript{b}International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico
Innovations for Sustainable Intensification through CA based system optimization approach

- Short duration, high yielding rice
- Wheat variety adapted to early seeding & CA
- Buffering seedling heat
- Early maturity, escape heat
- Extra window for Mungbean (Legume)

- System approach solutions
- High system productivity, profits, resource (water, nutrient) use efficiency
- Ensuring nutrition through legumes
- System sustainability and soil resilience
CA in Maize Systems: Adapting Climate Risks (200+ mm in 3 days in end of June 2017) in Haryana, India

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

6.38 t/ha

5.03 t/ha
CA Innovations in Sugarcane Systems
Sustainable intensification of rainfed cotton systems in Karnataka- small relay planter
Innovation with multiple wins: The Happy Seeder + Super SMS
Adaptation, Mitigation : Co-benefits

Mitigation efficiency: RW system (Sapkota et al., 2017, Sustainability)

Carbon gain after seven years of CA (Sapkota et al., 2017, Soil Use & Management)

• GHG intensity (blue) and grain yield (green) under various N rate Rice and wheat in Karnal and Vaishali CSV.

• The number at the bottom to each bar represents the number of samples in each N bin (Sapkota et al., 2017, Mitigation & Adaption for Glob change)
Long-term Trials on CA in Eastern IGP: Yield changes with different management scenarios at varying probability (11 years)

- In long-run, CA (no-till + residues) provides more stable yields at higher probability levels
- Partial CA (no-till without residue as well as no-till-conventional till cycle) are prone to lower yield stability at high probability even compared to conventional till based management
# Addressing Water-Energy-Food (FEW) Nexus in NW India (Layering CA with Fertigation, Solar energy)

<table>
<thead>
<tr>
<th>System magt</th>
<th>Irrigation method and energy source</th>
<th>System yield (t ha(^{-1}) yr(^{-1}))</th>
<th>System net income (USD ha(^{-1}) yr(^{-1}))</th>
<th>System water use (cm ha(^{-1}) yr(^{-1}))</th>
<th>System energy use (kWh ha(^{-1}) yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZTDSR-ZTW</td>
<td>SSD with solar power</td>
<td>12.33c</td>
<td>2094</td>
<td>96d</td>
<td>3663</td>
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<td>ZTDSR-ZTW</td>
<td>Flood</td>
<td>11.94c</td>
<td>2000</td>
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<td>TPR-CTW</td>
<td>Flood</td>
<td>12.18c</td>
<td>1909</td>
<td>181f</td>
<td>6686</td>
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<tr>
<td>PBM-PBW</td>
<td>SSD with solar power</td>
<td>13.67a</td>
<td>2357</td>
<td>29a</td>
<td>1249</td>
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<tr>
<td>PBM-PBW</td>
<td>Furrow irrigation</td>
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<td>2318</td>
<td>49b</td>
<td>1714</td>
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<tr>
<td>CTM-CTW</td>
<td>Flood</td>
<td>12.56bc</td>
<td>2087</td>
<td>59c</td>
<td>2027</td>
</tr>
</tbody>
</table>

- CA + micro-irrigation within RW system: same yields with 85 cm /ha/yr less water, half energy use and USD 185/ha/yr higher income
- CA + micro irrigation in MW system: 1.5 t/ha/yr more yield, 152 cm water saving with one quarter energy use and USD 450 /ha/yr more profit compared to conventional RW system in NW India

*Collaborative research of CIMMYT-BISA-PAU, Ludhiana, Punjab*
Smallholder Precision Nutrient Management: Nutrient Expert DSS (n=4500)

Soil Health Cards, Neem Coated Urea, Farmer Access, residues, legumes etc Decision guide considering spatial and temporal variability

Synthesized from CVS database by ML Jat, Tek Sapkota et al (CIMMYT-CCAFS)
Smallholder Precision Nutrient Management: GreenSeeker (n=3500, CSVs)

Extension agents, service providers, young farmers, crop advisors

Synthesized from CVS database by ML Jat, Tek Sapkota et al (CIMMYT-CCAFS)
Nitrogen Management in CA Alone Can Make a Big Difference
Nitrogen and Sustainable Development Goals

Source: Stirling et al (2018), CIMMYT
Evidence on Cost-effective opportunities for climate change mitigation in India

- All options are climate smart
- Technical Mitigation potential = 86 MtCO$_2$e/year
- 80% of mitigation potential achieved via cost saving options

Sapkota et al: Under publication in Global Change Biology
Exploring windows of opportunity

Risks → Challenges → Opportunities

Demographic → Social → Economic → Market

Current practices → Recombine → New practices

Objectives → Select → Constraints

Systems Based and Locally Adapted Solutions
Targeting with Clarity of Objectives

Ecosystem Services

Original farm configuration

Farm profitability

- Housing
- Intensive grassland
- Extensive grassland
- Maize
- Wheat
- Woodland

Original farm configuration
Science Based Optimization of Farming System Using FarmDesign

Existing Prototype Configuration

**Selected (crop areas in ha):**
- Rice-Wheat: 0.3
- Orchard: 0.22
- boundary plantation: 0.04
- Fish: 0.1
- Sorghum-potato-Maize: 0.3
- sugarcane: 0.4
- napier grass: 0.1

Operating profit: INR 350K/year

Alternate Optimized Configuration using FarmDesign

**Selected (crop areas in ha):**
- Rice-Wheat: 0.349
- Orchard: 0.22
- boundary plantation: 0.193
- Fish: 0.1
- Sorghum-potato-Maize: 0.261
- sugarcane: 0.219
- napier grass: 0.154

Operating profit: INR 410K/year

Soil Carbon Loss Vs Operating Profit with Existing and Optimized Farming System

Existing Farm

Alternate (INR 370-415K)
CLIMATE SMART VILLAGE (CSV) PROGRAM
“A community based holistic approach for empowering farm families for building resilience against climatic risks”
Technology led business models for scaling

Enhancing the role of private sector in scaling agriculture technologies

Business models of SMEs as a mechanism for scaling Climate Smart Technologies: The case of Punjab, India

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Right Policies Are Critical
Thank you for your interest!

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