Conservation Agriculture and Ecosystem Services: Integrating Power of Practices, Policies and People (PPP) is a Must for Impact at Scale

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Presentation structure

• Key challenges in agriculture
• What CA is all about?
• Overview of CA-history, adoption etc
• CA practices in South Asia
  ✓ Meta analysis results
  ✓ Evidence base on multiple wins
• Some examples of CA and ecosystem services
• Examples on SDGs
• Cost effective climate Change mitigation
• Policies
• Integrating with Socio-ecological system
Agricultural Issue, Concerns

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

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

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

Twin Challenge: Doubling Farmer’s income with sustaining natural resources under emerging climatic risks
Part of Solutions: Conservation Agriculture

CA ++ (Adapted component technologies)
- Micro-irrigation/fertigation
- Precision nutrient management
- Weed management
- Scale-appropriate mechanisation
- Solar energy
- GxExM
History and Adoption of CA (2015/16). Since 2008/09 increasing at 10 M ha annually

Source: Kassam et al (2017)
### Area of cropland under CA by continent – 2015/16

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

<table>
<thead>
<tr>
<th>Continent</th>
<th>Area (Mill. ha)</th>
<th>Per cent of global total</th>
<th>Per cent of arable land of reporting countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>South America</td>
<td>69.9 (49.6)*</td>
<td>39.0 (40.9)#</td>
<td>63.2</td>
</tr>
<tr>
<td>North America</td>
<td>63.2 (40.0)</td>
<td>35.2 (58.0)</td>
<td>28.1</td>
</tr>
<tr>
<td>Australia &amp; NZ</td>
<td>22.7 (12.2)</td>
<td>12.7 (86.1)</td>
<td>45.5+</td>
</tr>
<tr>
<td>Asia</td>
<td>13.2 (2.6)</td>
<td>7.4 (408)</td>
<td>3.8</td>
</tr>
<tr>
<td>Russia &amp; Ukraine</td>
<td>5.2 (0.1)</td>
<td>2.9 (5000)</td>
<td>3.3</td>
</tr>
<tr>
<td>Africa</td>
<td>2.7 (0.5)</td>
<td>1.5 (447)</td>
<td>2.0</td>
</tr>
<tr>
<td>Europe</td>
<td>2.5 (1.6)</td>
<td>1.4 (56.3)</td>
<td>3.5</td>
</tr>
<tr>
<td>Global total</td>
<td>179.5 (107)*</td>
<td>100 (69.2)#</td>
<td>12.5 (7.4)*</td>
</tr>
</tbody>
</table>

* \(\text{Area}^\text{*} \text{2008/9} \)

\# \% change since 2008/09

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

Source: Kassam et al (2017)
Asia --13.2+ Mha in 2015/16 (2008/09 - 2.6 Mha, 408% increase)

Countries now reporting CA area:

South Asia: India, Pakistan, Bangladesh, 
Southeast & East Asia: Laos, Cambodia, Vietnam, China, North Korea 
Central Asia: Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan 
West Asia: Iran, Turkey, Azerbaijan, Lebanon, Syria, Iraq

Source: Kassam et al (2017)
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)
A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production

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CA based in Intensive Cereal Systems in NW India: Productivity, Profitability, Soil quality and Environmental footprints (8 yr average)

<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>
</tr>
</thead>
<tbody>
<tr>
<td>Conventiona l RW</td>
<td>12.40</td>
<td>2557</td>
<td>75225</td>
<td>1361</td>
<td>0.45</td>
<td>6.3</td>
</tr>
<tr>
<td>CA based RW</td>
<td>13.17 (6)</td>
<td>1868 (-27)</td>
<td>57833 (-23)</td>
<td>1629 (20)</td>
<td>0.90 (100)</td>
<td>4.9 (-22)</td>
</tr>
<tr>
<td>CA based MW</td>
<td>14.09 (14)</td>
<td>738 (-71)</td>
<td>39376 (-48)</td>
<td>2122 (56)</td>
<td>0.84 (87)</td>
<td>4.5 (-29)</td>
</tr>
</tbody>
</table>

*In parenthesis= % change over conventional system

ICAR-CSSRI-CIMMYT Collaborative Research
Yield Trends-Maize-Wheat Rotation

- **ZT-Flat**
  - Linear: $y = 0.700x + 9.363; R^2 = 0.729$

- **PB**
  - Linear: $y = 0.649x + 9.753; R^2 = 0.719$

- **CT-Flat**
  - Linear: $y = 0.356x + 9.564; R^2 = 0.636$

Source: Parihar et al ICAR-IARI, New Delhi
CA in Wheat Systems Adapting to Terminal Heat

Days after sowing
Temperature difference (°C)
Residue retained
Residue removed

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

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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
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

Source: Jat et al (2019)
### 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>
</tr>
<tr>
<td>ZTDSR-ZTW</td>
<td>Flood</td>
<td>11.94c</td>
<td>2000</td>
<td>167e</td>
<td>6151</td>
</tr>
<tr>
<td>TPR-CTW</td>
<td>Flood</td>
<td>12.18c</td>
<td>1909</td>
<td>181f</td>
<td>6686</td>
</tr>
<tr>
<td>PBM-PBW</td>
<td>SSD with solar power</td>
<td>13.67a</td>
<td>2357</td>
<td>29a</td>
<td>1249</td>
</tr>
<tr>
<td>PBM-PBW</td>
<td>Furrow irrigation</td>
<td>13.24ab</td>
<td>2318</td>
<td>49b</td>
<td>1714</td>
</tr>
<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
Some Examples for Ecosystem Services
Evidence of Ecosystem Services from CA in Irrigated Rice-Wheat System

Improved soil health
(SOC 0.5 t/ha/yr)

Reduced weather risks
(High adaptability and Low CV in crop yield)

Reduce Chemical load
(20-25 kg N/ha, Less herbicide)

More crop per drop: Save irrigation water
Rice-wheat-mungbean: 40-50 ha-cm/yr

More profit: Lower costs and higher yields
(Profit 12000-15000/ha/yr)

Lower GHGs emission
(~1 t CO2-eq/ha/yr)

ICAR-CSSRI-CIMMYT Collaborative research
Residue Management

Monetary cost of converting biomass into soil organic matter/soil organic carbon (C).

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount (kg)</th>
<th>Price (US$ kg⁻¹)</th>
<th>Total price (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residues</td>
<td>62,000*</td>
<td>0.038</td>
<td>2,350</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>833</td>
<td>0.67</td>
<td>558</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>200</td>
<td>1.94</td>
<td>388</td>
</tr>
<tr>
<td>Sulfur</td>
<td>143</td>
<td>0.57</td>
<td>82</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>3,384</td>
</tr>
</tbody>
</table>

*Assuming conversions of biomass C at 35%, and C combustion in residues of 45% = (10⁴ kg ÷ 0.35) ÷ 0.45 = 62,000 kg.

Cost calculations for 10 t C

Total Cost= US$ 3384
Monetary gains= US$2057
Net cost= US$ 1327 (US$ 0.13/kg)
C Sequestration per ha = 300 kg
Cost of C per ha = ~ US$ 40/ha

Source: Lal (2014)
Laser leveling

Function
Reduced topographic variability, increased yields & input efficiency

Service
Precise spread of water across field

Benefits
Increased WP
Increased yield
Reduced GHGs

Value
Reduced energy for water pumping/irrigation cost
(US$ 20/ha)

Service
Water saving/low energy use for pumping (~20 cm/yr)

Benefits
Adapting to excess water/flooding
Better establishment & yields

Value
Higher yields (US$ 50/ha/yr)

Service
Save Fert Nitrogen (20kg/ha)

Benefits
Increase NUE, Reduced GHGs
Increased yield

Value
N cost
(US$ 15/ha)

Laser leveling

Flood Irrigation

Conceptualized by ML Jat (CIMMYT)
No-till farming

Intensive tillage

Function
- Direct drilling, reduced soil movement

Service
- Low soil respiration
- Fuel saving (~100 l/ha/yr)

Benefits
- Increased SOM
- Reduced GHGs (2-4 t/ha/yr)

Value
(US$ 50/ha/yr)

Service
- Implement manufacturing/wear/teat

Benefits
- Reduced GHGs

Value
(US$ 20/ha/yr)

Value
(US$ 100/ha/yr)

~2 mha

Service
- Save Fert Nitrogen (40 kg/ha)

Benefit
- Increase NUE, Reduced GHGs, Increased yield

Value
- N cost (US$ 30/ha)

Conceptualized by ML Jat (CIMMYT)
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

Right Policies Are Critical
Integrating with Socio-ecological system is a Must
Interaction between Agro-ecosystems, Agri-food systems and Socio-Ecosystems (Hubeau et al. 2016)

• Beyond public policies, social processes having major environmental effects
• These processes determine the relationship between supply and demand, through the agri-food system, affecting the dynamics of local, regional and global agroecosystems
• Understanding and integration of environmental impacts of diets by consumers is a major mechanism determining the relationship between societies and agro-ecosystems, promoting some types of agricultural production.
Thank you for your interest!