Climate Smart Agriculture and Mechanization in India

Presentation by

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UNITED NATIONS ESCAP
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CLIMATE CHANGE SCENARIO IN SOUTH ASIA

Period	Temperature Increase, ^0C		Precipitation, %	
	Dec-Feb (*Rabi*)	June-Aug (*Kharif*)	Dec-Feb (*Rabi*)	June-Aug (*Kharif*)
2010-2039	1.17	0.54	-3	5
2040-2069	3.16	1.71	0	13
2070-2099	5.44	3.14	-16	26

CO_2 levels: ***393 ppm by 2020;***
543 ppm by 2050
789 ppm by 2080

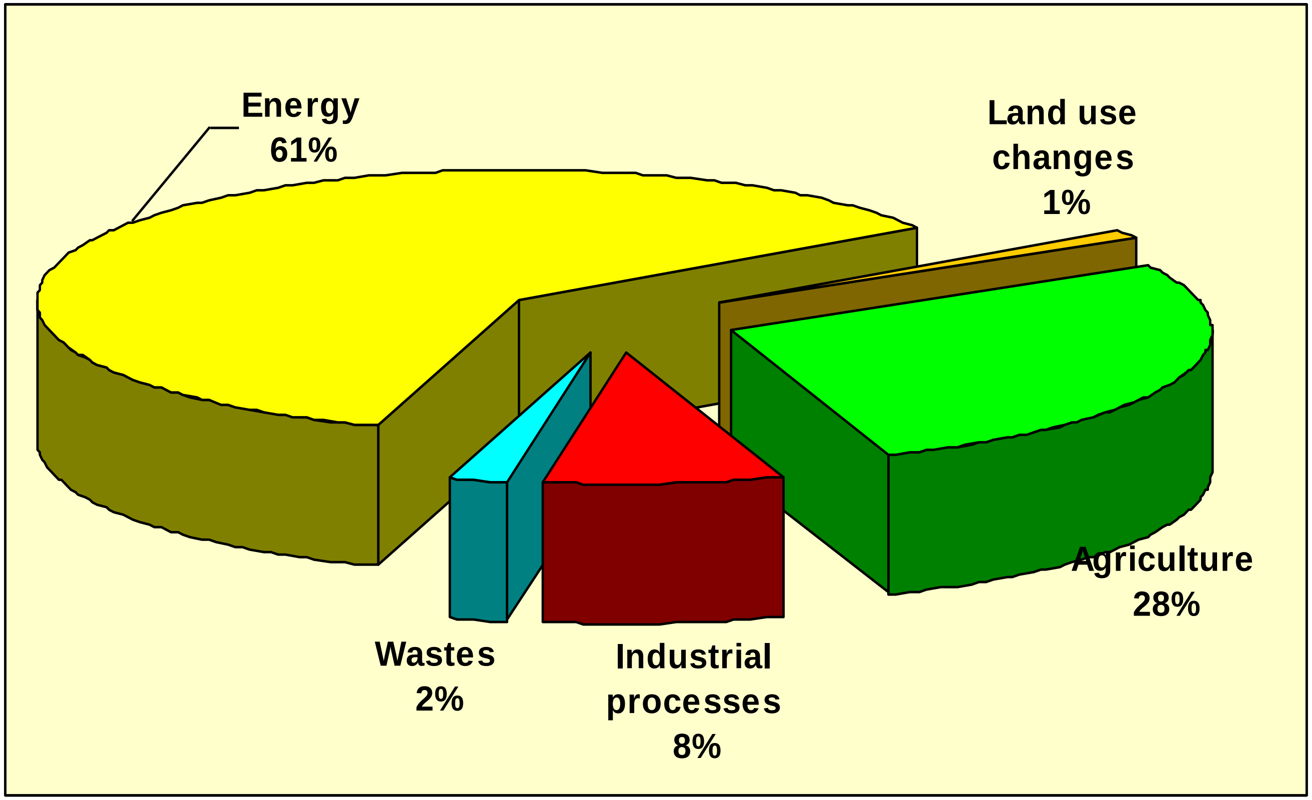
Source: IPCC, 2007

PROJECTED IMPACTS OF CLIMATE CHANGE ON INDIAN AGRICULTURE

- Productivity of cereals would decrease (due to increase in temperature and decrease in water availability (especially in Indo-Gangetic plains).
- Global reports indicate a loss of 10-40% in crop production by 2100.
- Greater loss expected in rabi. Every 1^{o}C increase in temp. reduces wheat production by 4-5 million tons. Loss of only 1-2 million tons, if farmers perform sowing and planting operations in time using improved machinery.

- **Increase in temperature would increase fertilizer requirement for the same production targets; and result in higher emissions.**
- **Increase in sea and river water temperatures are likely to affect fish breeding, migration, and harvest.**
- **New ‘flooded’ areas may become available for fisheries in coastal regions.**
- **Increased requirement of water, shelter, and energy for livestock; implications for milk production**
- **Need of machinery and practices for judicious application of inputs, conservation of energy and reduce the emission.**

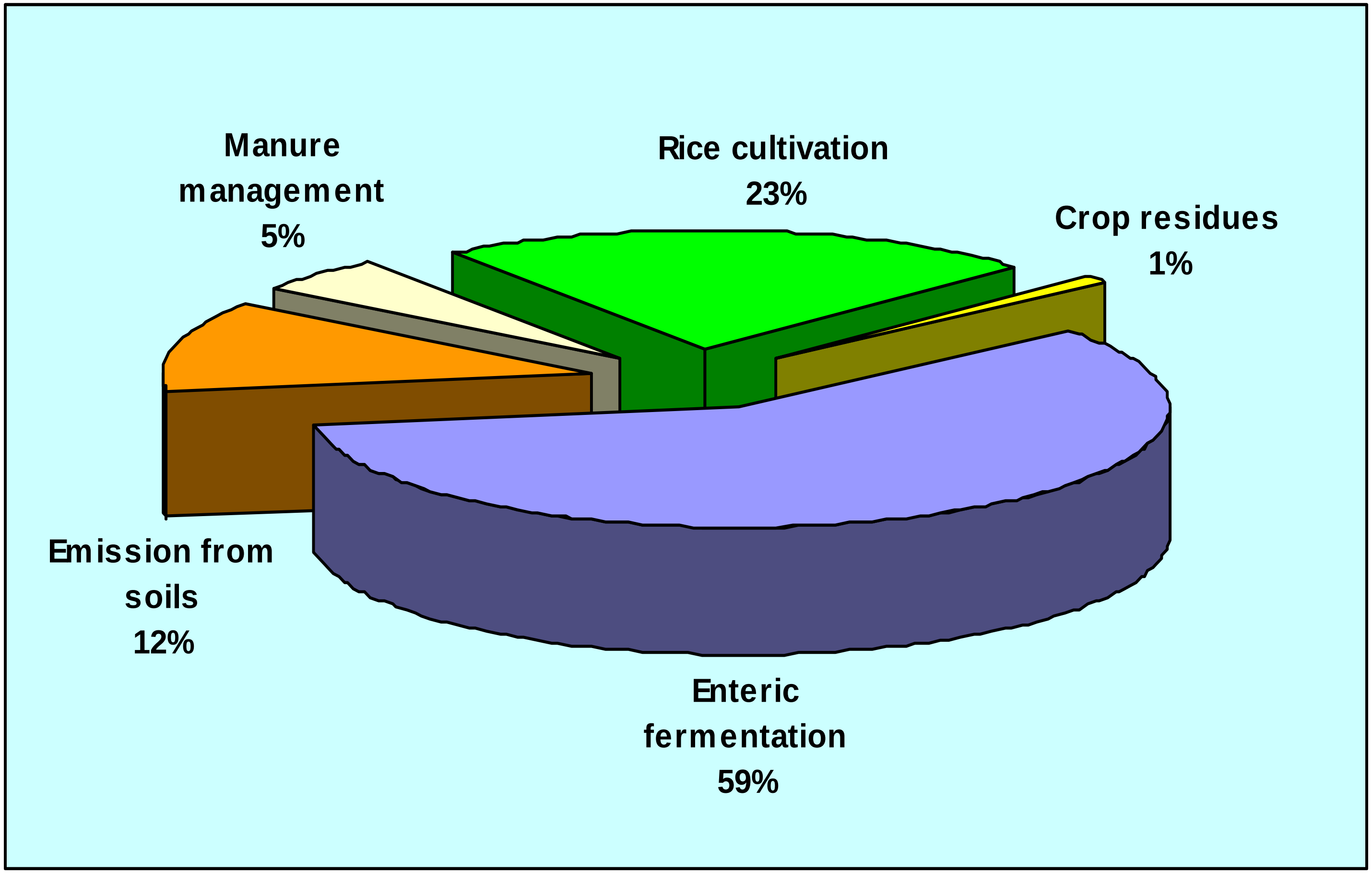
CONTRIBUTION OF DIFFERENT SECTORS IN INDIA TO CLIMATE CHANGE (GHG EMISSION)



Fossil fuel used in agriculture considered in energy sector

Source: India's Initial National Communication on Climate Change, 2004

AGRICULTURE SECTORS CONTRIBUTION TO CLIMATE CHANGE IN INDIA



Source:
India's Initial National Communication on Climate Change, 2004

HOW CAN WE REDUCE EMISSION OF GREENHOUSE GASES FROM AGRICULTURE?

- Improve management of water and fertilizer in rice; use nitrification inhibitors, fertilizer placement schedules
- Improve management of livestock population and its diet
- Increase soil carbon, promote minimal tillage, bed planting and residue management
- Improve energy use efficiency in agriculture: better designs of machinery, and by conservation practices

TECHNOLOGIES TO MITIGATE EFFECT OF CLIMATE CHANGE RISK

- **Resource conservation technologies (RCT), take up new ways of managing their resources for more productively and, providing a way to solve emerging problems of climate change due to reducing the emissions of GHGs.**
- **Machinery and practices for RCT can reduce the emissions of fossil fuels compared to conventional agriculture by up to 60 per cent.**
- **The levels of carbon to be captured in the soil depend upon the climate and production system. On an average 0.1-0.5 t.ha-l y-l of organic carbon can be captured under humid temperate conditions. For this farm equipment like, straw shavers and rotovators are required for incorporation of crop residue into soil.**

ENGINEERING INTERVENTION TO RESOURCE CONSERVATION AGRICULTURE

- Minimum soil disturbance (Minimum or zero tillage)
- Reduce soil compaction (controlled traffic/ raised/ permanent beds cultivation technology)
- Reduce inputs (Timely and judicious application)
- Increase organic carbon in soil (Straw incorporation in soil or by spreading over the soil)
- Minimize water requirement and ensure uniform moisture increasing crop yields (Precision land leveling and precision irrigation)
- Economise energy use & reduce GHGs Emission

MACHINERY AND PRACTICES FOR CLIMATE RESILIENT AGRICULTURE

Zero/minimum tillage-seeding

Animal drawn zero till seed cum fertilizer drill

Furrow opener	Inverted 'T'
Draft	700 N
Power	A pair of bullocks
Field capacity	0.04 - 0.05 ha/h

No till drill

Furrow opener	Inverted 'T'
Size	9 /11 rows
Power	35 - 50 hp tractor
Field capacity	0.30 - 0.32 ha/h

Strip till drill

Furrow opener Rotary blade strips
& shoe type:9 row

Power 35 - 50 hp tractor

Field capacity 0.22 - 0.25 ha/h

Rotary slit till drill

Furrow opener Rotary cutters &
shoe type: 9 rows

Power 35 – 50 hp tractor Field

capacity 0.36 - 0.40 ha/h

Broad bed former cum seeder

Bed size 1200 mm top width
1500 mm bottom width
100 mm bed height

Power 45- 50 hp tractor

Field capacity 0.30 - 0.32 ha/h

PERFORMANCE OF NO TILLAGE MACHINERY IN TERMS OF ENERGY AND ENVIRONMENT

Particulars	No till drill	Strip till drill	Rotary slit till drill	Bed former cum seeder	Conventional (3-ploughing + seed drill)
Time required (h/ha)	3.23 (70.2)	4.17 (61.5)	2.50 (76.8)	3.33 (69.2)	10.82
Fuel used (l/ha)	11.30 (67.4)	17.80 (49.5)	10.0 (71.0)	13.33 (61.5)	34.62
Operational energy, MJ/ha	648.96 (67.2)	1002 (49.3)	565.0 (71.4)	765.5 (61.3)	1976.62
Operational cost, Rs/ha	639.54 (66.4)	979.9 (48.5)	1000.0 (70.6)	754.4 (60.36)	1903.04
CO_2 emission kg/ha	29.38 (67.4)	46.28 (48.6)	26.0 (71.0)	34.66 (61.5)	90.0

RESOURCE CONSERVATION MACHINERY

Roto drill

Furrow opener	Rotary blade strips & shoe type: 9 row
Power	45 - 50 hp tractor
Field capacity	0.25 - 0.30 ha/h

Till plant machine

Furrow opener	Shoe type: 9 row
Power	35 - 45 hp tractor
Field capacity	0.22 - 0.25 ha/h

Rotovator

Rotary blade	L type blade mounted on a rotary shaft
Power	35 - 50 hp tractor
Field capacity	0.22- 0.25 ha/h

PERFORMANCE OF RESOURCE CONSERVATION MACHINERY IN TERMS OF ENERGY AND ENVIRONMENT

Particulars	Rotovator + seed cum fert. drill	Roto till drill	Till plant machine	Conventional (3-ploughing + seed drill)
Fuel used (l/ha)	20.0 (42.2)	13.8 (60.1)	5.60 (81.5)	34.62
Operational energy (MJ/ha)	**1135.65 (42.6)**	**783.6 (60.3)**	**322.0 (83.7)**	**1976.62**
Cost of operation (Rs/ha)	1093.0 (42.56)	1000 (47.1)	566.44 (83.34)	1903.04
CO_2 emission, kg/ha	**52.0 (42.22)**	**35.88 (60.1)**	**14.56(83.8)**	**90.0**

EFFECT OF FOSSIL FUEL ON GHG EMISSION UNDER DIFFERENT CULTIVATION SYSTEMS

Cultivation system	Average fossil fuel used, l/ha	GHG emission, CO_2 in kg
Conventional tillage system	48.5/crop	126
Reduced/no-tillage system	35.9/crop	93.3
Permanent bed cultivation	15.9/crop	41.3

- **In India about 3.43 million ha is under no tillage for rice-wheat cultivation.**
- **Zero tillage cultivation on 3.43 million ha area saved CO_2 emission of 224.3 million kg**
- **Permanent bed cultivation system (Bed former cum seeder/planter) on 3.43 million ha area would save CO_2 emission of 581.04 million kg**

EFFECT OF TILLAGE TREATMENTS ON BUILD OF ORGANIC CARBON IN SOIL

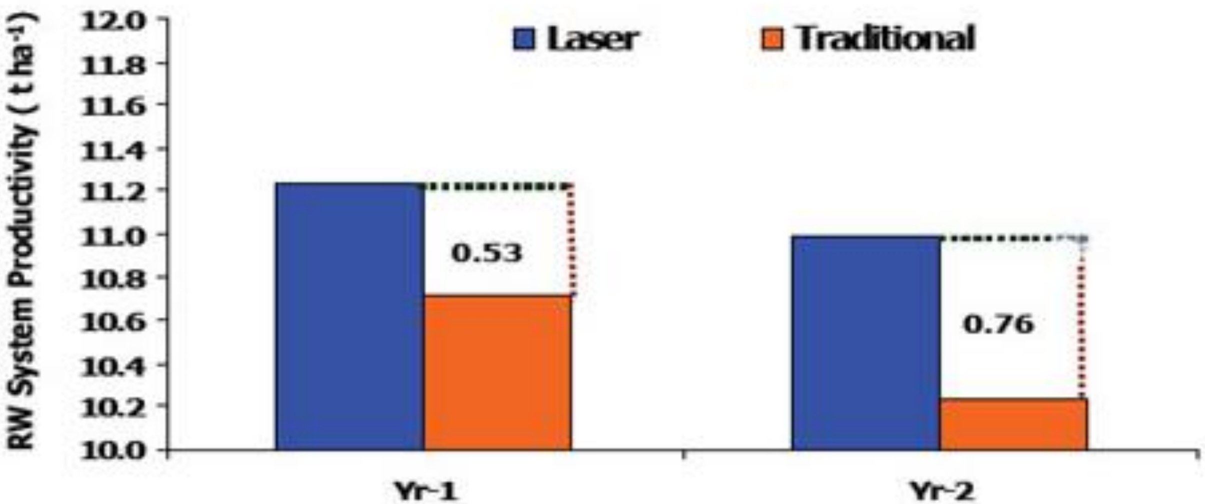
Tillage treatment	Organic C (g/kg) at soil depth	
	0 – 50 mm	50 – 200 mm
Conventional tillage-seeding	5.42	5.26
Minimum/no tillage-seeding	6.16	6.00

Source: ICAR-CRIDA Annual Report - 2009-10

- It is estimated that global conversion of all crop lands to conservation tillage (CT) can sequest 25 billion tons of C over 5 years. Based on the assumption that CT sequests 0.3 ton C/ha/year Chicago Climate Exchange (CCX) payments.
- For every tonne of carbon lost from soil adds 3.67 tons of CO_2 gas to the atmosphere.

LASER GUIDED PRECISION LEVELER:
A PRECURSOR FOR RESOURCE CONSERVATION

Land leveling effects on RW system productivity



Effect of laser leveling and grading on crop yield (t/ha)

Crop	Laser leveled	Conventionally graded	Unleveled
Paddy	5.78 (11%)	5.25	-
Wheat	4.7 (7 %)	4.4	4.08
Pigeon pea	33.6 (16%)	3.1	2.66
Soybean	1.66 (10.7%)	1.5	1.18

SPECTRAL REFLECTANCE BASED VARIABLE RATE UREA APPLICATOR

Variable rate urea application in wheat (top dressing)

- Suitable for top dressing of urea in rice and wheat crop.
- Reduction in carbon emissions as 1.73 kg CE/1000 kg grain, for paddy and 2.22 kg CE/1000 kg grain for wheat as compared to conventional top dressing method due to saving of N.

MACHINERY FOR RICE PRODUCTION

Issues	Strategies
• Declining levels of soil organic matter • Widening N: P : K Ratio • Micro-nutrient deficiencies • Declining response in terms of grains/ kg fertilizer • Low nutrient use efficiency	• Integrated Nutrient Management • Conservation Agriculture Machinery & Practices

DIRECT SEEDED RICE–CA PRACTICES

Direct Seeded Rice Cultivation

- Saves water by 15-20 %
- Efficient weed management in line sowing
- Reduced cost of cultivation
- Yields almost equivalent to transplanted crop

System of Rice Intensification (SRI)

- Most suitable for small and marginal farmers
- Labour intensive
- Precision operations
- Efficient utilization of water and nutrients
- Higher returns

IRRIGATION EQUIPMENT AND PRACTICES

Emission from diesel engine/electric pump sets

Parameter	Diesel pumps	Electric pumps
Number, million, 2015-16	8.121	26.578
Fuel consumption, l/h (Avg. size 5 hp)	1.0	3.7 (kWh)
Command area/pump, ha	4 ha	5 ha
Average area irrigated, million-ha/year	30.0	59.0
Average operating hour/year/pump	400	500
Average diesel/ electricity consumption million-l/year and kWh/year	3248.2	49169.3
CO_2 emitted, mt/year	8.45	65.54
Total emission, mt/year	74 .00	

EFFICIENT IRRIGATION PRACTICES TO REDUCE GHG EMISSIONS

Particulars	Surface (Pumping)	Sprinkler	Drip
Conveyance efficiency, %	40-50 (Canal 60-70 (Well)	100	100
Application efficiency, %	40-60	70-80	90
Moisture evaporation, %	30-40	30-40	20-25
Overall efficiency,%	30-35	50-60	80-90

- Energy efficient irrigation systems are moisture stress based sprinkler and drip irrigation, which are used to apply the proper amount of water as per the soil moisture – plant stress.
- Water use efficiency of both the system is very high and saving in water is 30-70% as compared to conventional flood irrigation method.
- Adoption of these two systems would reduce 30-70% GHG emissions during the irrigation of crops in India.

MACHINERY FOR RESIDUE MANAGEMENT

Surplus of crop residues in India (million tonne $year^{-1}$)			
Residue generation (MNRE, 2009)	Residue surplus (MNRE, 2009)	Residue burned (IPCC coeff.)	Residue burned (Pathak et al. 2010)
501.76	**140.84**	**83.66**	**92.81**

- **The burning of crop residue in India has resulted 6.606 million tonnes equivalent CO_2 emission/year (INCCA-2010).**
- **One tonne straw on burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2.**

Residues left in field with different land preparation activities	
Field operation	Residue left, %
Residue after harvest with combine	80-90
Moldboard plough	0-15
Plough and chisel	0-10
Disc (2 operations)	15-20
Chisel (2 operations)	30-40
Cultivator (1 operation)	50-70
Direct seeding/planting	80-90

RESIDUE MANAGEMENT THROUGH RCT PRACTICES

Stubble saver	Cuts and mixes the straw in the field and reduced subsequent farm operations
Rotovator	Cuts and mixes the straw in the field and pulverization of the soil in a single pass, Sowing can be performed by using a 9-row seed cum fertilizer drill.
Happy seeder	Simultaneously cuts the standing straw, plants wheat and throw the straw on the planted seeds
Rotary disc no till drill	Rotary disc cuts the residue and make a slit for sowing of seed. The machine is use for direct sowing of paddy over wheat straw under dry condition.

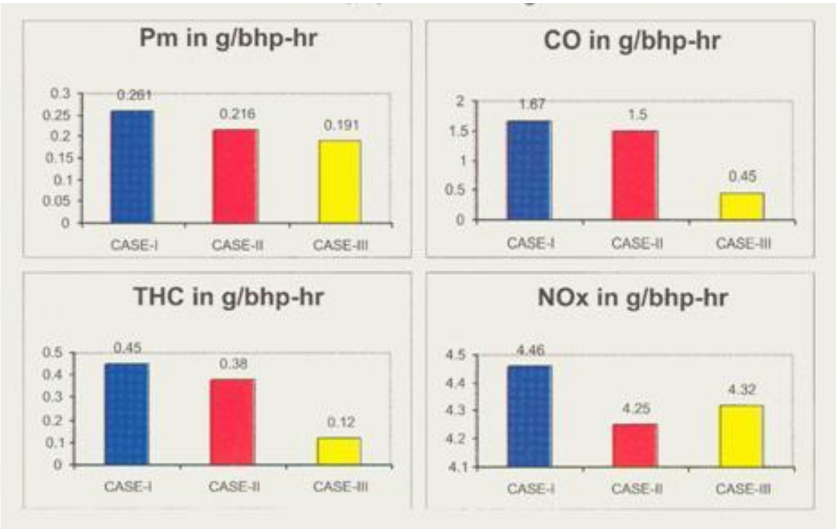
Straw baler	It cuts the straw from combine harvested fields and makes bundles. Straw burning causes environmental pollution
Straw reaper	It cuts the standing straw left in the field after combining and throw it in a trolley at the rear. 1000 kg of straw/ha & 40-50 kg/ha grain can be recovered.
Straw combine	The machine cuts the standing crop residue left after combining and send the threshed straw in a trolley integrated with tractor. Trolley is raised from one side to empty the straw through a hydraulic system

EFFECT OF MACHINERY AND PRACTICES ON STRAW INCORPORATION AND GHG EMISSIONS

Machinery used	Time h/ha	Diesel l/ha	Operational cost, Rs/ha	Total Cost, Rs/ha	% straw incorporated	CO_2 emission Kg/ha
Stubble shaver (1) MB plough (1) Rotovator (1) Seed cum fert. drill (1)	2.75 5.00 3.00 3.70	11.00 20.00 12.00 13.12	515 1750 1500 1100	4865	- 76.70 13.00 -	145.12
Stubble shaver (1) Rotovator (1) Seed cum fert. drill (1)	2.75 3.2 4.0	11.00 12.80 14.00	515 1600 1190	3305	- 60.5 -	98.28
Rotovator (1) Seed cum fert. drill (1)	4.5 4.8	21.60 16.80	2250 1427	3677	10.0 -	99.84
Happy seeder (Direct seeding)	4.00	16.00	1500	1500	100	41.6
Rotary disc no till drill (Direct sowing)	4.00	16.00	1500	1500	100	41.6

BIO-DIESEL AS FOSSIL FUEL TO REDUCE GHG EMISSION

- **Biodiesel is the only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the Clean Air Act Section 211(b).**
- **The life-cycle production and use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel.**



CASE-I: Petrodiesel with 0.05% sulphur.

CASE-II: 20% biodiesel with 3-degree injection timing adjustment.

CASE-III: CASE-II + Catalytic Converter (Source: Twin Rivers Technologies, USA)

ISSUES IN STRAW MANAGEMENT

- **Incorporation of cereal crop residues immediately before sowing/transplanting into wheat or rice significantly lowers crop yield due to immobilization of N.**

- **Accident of termite attack on residue has been reported in India.**

- **Optimization of rice-wheat straw quantity to be incorporated yearly and need to enhance decomposition of machine-harvested straw to improve soil health.**

- **Use of crop residues for livestock feed and fuel should be identified and their characterisation to be done as nutrient and fuel properties for animal feed and fuel for briquetting and bio-oil production.**

CASE STUDY-I: BED PLANTING TECHNOLOGY FOR CLIMATE RESILIENT AGRICULTURE

Climate vulnerability: Extreme rainfall events, prolonged dry spells and waterlogging at different crop growth stages.

Existing practice: Sowing of soybean crop by tractor drawn seed cum fertilizer drill in conventional flat bed system. During extreme rainfall events, the crop gets affected either due to dry spells or waterlogging due to lack of proper drainage.

Resilient practice / technology

- Broad bed cultivation system for *in-situ* soil and water conservation and proper drainage in deep black soils.
- In order to encourage the farmers to change traditional practice, broad bed former cum seeder was introduced in village Khachhi Barkheda Bhopal, Madhya Pradesh.
- Four rows of soybean crop is shown on broad bed: top width 1200 mm, bottom width 1500 mm, height 100 mm at 300 mm row spacing

IMPACT OF TECHNOLOGY

- Eight farmers of Kachhi Barkheda village, Bhopal, Madhya Pradesh sown the soybean crop beds by using tractor mounted broad bed former cum seeder in 26.2 ha area and spent around Rs. 2000/ha for the its operation.
- Earlier they practiced tillage operations such as ploughing, harrowing and sowing on flat beds with tractor mounted implements that cost Rs. 2500/ha.
- During heavy rain excess water drained out through furrows and there was no moisture stress during non- rainy days.

Performance of soybean in broad bed method of sowing

Particular	permanent bed cultivation	Farmers' practice	% increase in yield/income
Grain yield (kg/ha)	947	600	57.8
Total income (Rs/ha)	33666	20880	61.24
Net Return (Rs/ha)	18378	5476	235.6
B:C ratio	2.20	1.35	-

Improved technology:

- Increase water use efficiency (30-40%)
- Increase crop productivity (5-10%)
- Time saving (25-30%) in irrigation
- Water saving up to 25-30%
- Less moisture stress during non-rainy days
- Requires 20-25% lower seed rate
- Better weed management

Scope for upscaling

BBF for soybean was demonstrated in different states. Presently it is practiced on more than 50,000 ha in Madhya Pradesh.

Case study-II: *In situ* incorporation of crop residues

Climate Vulnerability:

Loss of organic matter, environment pollution, high temperature stress, and heat wave.

Existing Practice:

- Generally, farmers burn crop residues like stalks of wheat, paddy, maize, pigeon pea and cotton without recycling or removing.
- This harmful practice is leading to increased GHG emissions besides depriving crop residue to the soil.

Resilient practice / technology:

- In order to encourage farmers to change this practice, rotovator machine was introduced in village Bagroada, Bhopal, Madhya Pradesh.
- Rotovator preparers field for sowing in one pass. It mixes and incorporates the stubbles of previous crop thoroughly in the soil.
- The cost of implement is Rs. 1.2 lakhs and field capacity of the rotovator is 0.20-0.30 (4-5 ha/day).

Impact:

- **Three farmer of village Bagroada, Bhopal, Madhya Pradesh used rotovator for incorporating the maize/soybean crop residue on 12.8 ha area and spent around Rs.1600/ha for the its operation.**
- **Earlier they practiced tillage operations such as plouging and harrowing with tractor mounting implements that cost Rs 2500/ha.**

Performance of wheat crop sown after different type tillage operations in incorporated maize residues field

Parameters	Reduced tillage (one rotovator)	Conventional tillage	% increase in yield/income
Grain yield, t/ha	**5.00**	**4.00**	**25.0**
Net Return (Rs/ha)	39250	31165	**26.0**
B:C ratio	2.24	1.98	-
Residue incorporated, Kg/ha	**2280**	-	-

- *In situ* incorporation of crop residues has stopped the practice of burning which aggravates GHG emissions as one tonne crop residue on burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2.
- Rotovator use is gaining popularity in view of its multiple operation capabilities with greater energy efficiency. It sale has increased 1000 unit/year in MP.



Scope for upscaling

- *In situ* incorporation of maize/soybean residues was demonstrated in 1060 ha covering 1400 farmers across several districts of M. P. to stop the burning of crop residues in field.
- The yield of wheat crop by incorporation of maize/soybean crop residues has increased 25% as compared to conventional practice.
- There is scope for up scaling the technology in wheat, oilseed and pulses crop growing areas.

Potential of resource conservation machinery and practices to Reduce CO_2 Emissions in India

10 million ha of rice-wheat crop would be suitable for reduced tillage practices (RT) and more than 30% of crop residues on the soil surface.

The key values used in this calculation are:

- **Carbon sequestration under no-tillage (NT): 0.77 t C $ha^{-1}year^{-1}$**
- **Carbon sequestration under reduced tillage (RT): 0.50 t C $ha^{-1}year^{-1}$**
- **Reduced fuel consumption under NT: 44.2 l $ha^{-1}year^{-1}$**
- **Reduced fuel consumption under RT: 20.0 l $ha^{-1}year^{-1}$**
- **Percentage cultivated land suitable for NT: 30%**
- **Percentage cultivated land suitable for RT: 40%**

Potential carbon sequestration in the soil :

- **Conservation tillage practices sums up to around 35 million tonne per year,**
- **Represents a total yearly CO_2 mitigation of 130 million tonne.**
- **Saving of around 5.3 million tonne CO_2 $year^{-1}$ through less fuel consumption due to the reduction of tillage operations appears rather small.**
- **Together, this C sequestration with the CO_2 emission reduction would account for almost 40% of the 346 million tonne CO_2 $year^{-1}$.**

CONCLUSIONS

- In next decade, more food would be produced from limited land by making efficient use of natural resources with minimal impact on the environment.
- Indian agriculture is likely to suffer from losses due to climate change such as: heat, erratic weather, and decreased of water table in tube well irrigation system.
- Improved machinery and practices has been found very effective to reduce the GHG emissions from precise land leveling, no tillage seeding planting, and crop residue management.
- Encouraging long term research and development of technologies for sustainable management of crop production and natural resources to support the farmers with sustainable funding is urgently required.
- Costs of adaptation and mitigation are unknown but likely to be high; costs of inaction could be even higher.

Thank you.

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