The interaction between forestry, agriculture and climate change and implications for REDD
IIED, London, 20 November 2009

Conservation Agriculture for Sustainable Production Intensification and Climate Change Mitigation

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Outline

• Background
• Productive capacity & soil health
• What is Conservation Agriculture (CA)?
• History and Adoption of CA
• How does CA work? What does CA do?
• Conclusions
Challenge

• Intensive tillage-based agriculture not sustainable economically and environmentally.

• How to combine sustainability with production intensification in a changing climate – to reverse the observable trends of ‘conventional agriculture’ towards declining sustainability of land’s productive capacity, and ecosystem degradation.

• For this we need to understand and address the root causes of unsustainability and degradation, and respond to climate change.

• There is also the question of relating REDD to agriculture.
Productive capacity

Soil productive capacity (vs. fertility) is derived from five components which interact dynamically in space and time:

- **Physical**: architecture - pore structure
- **Hydrological**: moisture storage - infiltration
- **Chemical**: nutrients, CEC, dynamics
- **Biological**: soil life and non living fractions
- **Thermal**: metabolic rates

A productive soil is a living system and its health depends on managing it as a ‘complex’ biological system, not as a geological entity.
Soil health refers to the integration of biological with chemical and physical approaches to soil management for long-term sustainability of crop productivity with minimum negative impact on the environment. Healthy soils maintain a diverse community of soil organisms that help to control pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure...... (Wolf, 2000)
Soil health and tillage

Conventional tillage-based production systems at all levels of agricultural development do the opposite, and are a major source of degradation of soil health and productive capacity, and of the environment (including GHGe).

[The soil health definitions are readily compatible with the characteristics and objectives of Conservation Agriculture.]
Conventional: regular tillage, clean seedbed, exposed

Effects:
- Removal of cover
- Disruption of pores
- Destruction of structure
- Loss of organic matter
- Destruction of biological life & processes
Tillage-induced Carbon Dioxide Loss
components of soil productivity - adverse effects of tillage agriculture

Cumulative Carbon Dioxide Loss after 24 hours

\[ y = 0.0792x + 9.7647 \]

\[ R^2 = 0.9698 \]
Soil organic carbon and yield indicators over 100 years of cultivation in western Kenya

From Marenya & Barrett 2007
Erosion & water pollution from tillage agriculture

soil health & adverse effects of tillage agriculture

silting

text: picture: Dr. Strobel, LfA/Germany
Nitrate pollution from tillage agriculture

Monthly variations in nitrates, Itaipú dam in the year 1983

(Sorrenson, 1984)
Phosphate pollution from tillage agriculture

Monthy variations in phosphorus, Itaipú dam in the year 1983

(Sorrenson, 1984)
COMPARISON

A FARMER’S TRIAL – CLODS OF TOPSOIL FROM ADJACENT PLOTS, PARANÁ, BRAZIL (Shaxson 2007)

**PRO-BIOTIC**
Topsoil after 5 years with retention of crop residues and no-till seeding.

**ANTI-BIOTIC**
Topsoil after regularly-repeated disk-tillage, without retention of residues.
WHAT DOES IT LOOK LIKE CLOSE-UP?

SAME SOLIDS - DIFFERENT SPACES
IMPLICATIONS FOR ROOTS AND RIVERS

Shaxson (2007)
• The usefulness of the structure depends on the spaces, where all the interesting things happen.
• Such space-filled structures built by organisms. Shaxson (2007)
Consequences of tillage-based agriculture:

- loss of OM, porosity, biota (=decline in soil health)
- soil compaction & water loss as runoff
- soil loss as sediment
- loss of seeds, fertilizer, pesticides (erosion, leaching)
- less capacity to capture and slow release water & nutrients
- less efficiency of mineral fertilizer:
  “The crops have become ‘addicted’ to fertilizers”
- more pest problems (breakdown of natural control)
- falling total input efficiency
- declining yields
- reduced resilience
- reduced sustainability
A solution offered by CA

CA Systems based on three practices applied simultaneously, in conjunction with provision of sufficient plant nutrients, offer an entirely-appropriate solution, potentially able to slow and reverse these damages, and to minimise/avoid their repetition on newly-opened lands.
The combination of
• Minimum soil disturbance
  (Continuous 0-tillage &
   direct seeding)
• Permanent soil cover, &
• Crop rotations/associations
  applied simultaneously has
become known as
**Conservation Agriculture**

What is CA?
simulating
forest floor conditions
History and Adoption of CA

- **US Soil Conservation Service conservation tillage**
- **First no-till in the US**
- **Faulkner (UK) – Fukuoka (Japan)**
- **Commercial introduction of no-till/US**
- **First no-till demonstration in Brazil**
- **Oldrieve/Zimbabwe**
- **IITA no-till research**
- **Adoption Brazil plantio direto na palha**
- **Experiments in China, Indogangetic Plains**
- **Argentine, Paraguay**
- **New boost: Canada, Australia, Kazakhstan, Russia, China, Finland, Africa**

Timeline:
- **1930**: Dustbowl
- **1950**: Faulkner (UK) – Fukuoka (Japan)
- **1980**: First no-till demonstration in Brazil
- **1990**: IITA no-till research
- **2000**: New boost: Canada, Australia, Kazakhstan, Russia, China, Finland, Africa

Mill. ha:
- **100**: Dustbowl
- **50**: First no-till in the US
CA is increasing globally:

- Total area: 106 million ha (7% of cropland)
- South America: 49.6 million ha (46.6%)
- North America: 40.0 million ha (37.5%)
- Australia & NZ: 12.2 million ha (11.4%)
- Asia: 2.6 million ha (2.3%)
- Europe: 1.5 million ha (1.4%)
- Africa: 0.5 million ha (0.4%), huge potential in the moist savannas
Conservation Agriculture worldwide 106 Million ha

Canada 13
USA 27
Europe 0.5
Asia 3.3
Africa 0.5
Brazil 26
Paraguay 2.4
Argentina 20
Australia 12

History and Adoption of CA

(Derpsch, 2009)
Crop-livestock integration: new options with CA
Crop-livestock integration: new options with CA

12 years: soybean & Italian ryegrass in succession

controlled grazing in excess residues
Agroforestry

- Under CA less problems to integrate trees
- Additional biodiversity
- Habitat for wildlife/predators
What does CA do?

Land Preparation

Conventional: regularly full tillage

CA: planting holes, ripping or mulching
What does CA do?

Seeding/Planting

Conventional: clean seedbed

CA: direct seeding into mulch and moist soil
CA: A framework for ecosystem management in a number of production systems, facilitating

• Water retention in the ecosystem (infiltration)
• Erosion control
• Biodiversity
• Productivity
• Pest management
• Spiral of regeneration
• etc
Effect of CA on soil:

- CA builds soil, stops erosion, reverses degradation (1 mm new soil per year added)
- SOM increase 0.1-0.2% per year (also CEC)
- Stable spatial structure with
- Soil life (porosity, roots, fauna) storage and infiltration
- Increase in soil moisture
- Different rooting systems for more efficient use of nutrients
- Soil biological processes complement ecosystem functioning
What does CA do?

Production increase

Produção de grãos no Brasil

BRASIL - EXPANSÃO DA ÁREA CULTIVADA EM PLANTIO DIRETO

What does CA do?

Production increase

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What does CA do?
What does CA do?

Effect on production & plant nutrients over time

Wheat yield and nitrogen amount for different duration of no-tillage in Canada 2002 (Lafond 2003)

Grain yield (t/ha)

nitrogen (kg/ha)

20-year no-tillage
2-year no-tillage

Frank Dijkstra Farm, Ponta Grossa, Brazil, 1998

cited from Derpsch 2005

4 t/ha
8 t/ha

30% less fertilizer
3.6 t/ha

50% less fertilizer
2.2 t/ha

What does CA do?

Effect on production & plant nutrients over time

Grain yield (t/ha)

nitrogen (kg/ha)

20-year no-tillage
2-year no-tillage

Frank Dijkstra Farm, Ponta Grossa, Brazil, 1998

cited from Derpsch 2005
Effect of CA on water:

• Recharge of aquifer (permanent macro-pore structure in soil)
• Improved water quality (less leaching and erosion)
• More available water in soils (1 % OM = 150 m3/ha)
• Reduced water losses (evaporation)
• Better water efficiency (requirements -30%)
Gains in Rainfall Infiltration Rate with CA

What does CA do?

Landers 2007

Accumulated Infiltration rate [mm h⁻¹]

Time (min.)

- tillage + cover, measured
- no-till + cover, measured
- tillage, no cover, measured
- tillage + cover, calculated
- no-till + cover, calculated
- tillage, no cover, calculated

$I = 139,33t^{0,345}$
$R^2 = 0,8283$

$I = 54,253t^{0,3008}$
$R^2 = 0,7524$

$I = 277,5t^{0,1798}$
$R^2 = 0,9712$
Effect on pest management & biodiversity:

- Crop rotations and mulch elements for natural pest control (contributes to IPM)
- Healthier soil = healthier plants
- Over time pest and disease problems decrease (less pesticides)
- Pesticides must not interfere with biological processes
Weed management in CA:

First two years critical - herbicides are useful for sanitation

• General rule: avoid weeds to mature, avoid fallow/open soil surface; let seed bank decay

• Mulch cover, cover crops, crop rotations main tools

• Herbicide use over time declining

• CA without herbicides is possible

What does CA do?

Anderson, R.L. 2005

[Bar chart showing weeds (plts/m2) for W-CP, W-C-CP, and W-C-SB-Pea with values 60, 25, and 5 respectively]
CA and climate change:

• Adaptation through better water infiltration (less flooding)

• Adaptation through better drought/temperature tolerance

• Mitigation through emission reductions (less CO2 from fuel & soil, N2O, CH4)

• Mitigation through carbon sequestration up to 0.2 t.ha-1.y-1 C
What does CA do

Integrated CA systems

Soil structure & biota

Nutrient & water cycling

Crop Diversity

Plant Insect pests & diseases

No-Till plus OM Management

Weed management

Ecological Processes

Spiral of Regeneration & Intensification

Anderson, R.L. 2005
Advantages for the farmer: Farmer’s livelihood

• Mechanized Farmers:
  - less machinery & inputs
  - 70% fuel saving
  - stable & increased yields

• Smallholder farmers:
  - 50% labour saving
  - less drudgery, purchased inputs
  - stable & increased yields, food security

= better livelihood/income
Benefits for communities: Public goods
• Less pesticide use (-20%), less pollution
• Lower cost for water treatment
• More stable river flows
• Lower road/waterway maintenance
Global benefits: improving...

- Groundwater resources
- Soil resources
- Biodiversity
- Climate Change – GHGe & C seq
- Food security
Conclusions:

• Sustainable increase of global production with CA

• Reduce environmental footprint of agriculture - enhance resources base: “Collateral damage” to ecosystems unnecessary

• Improved biodiversity possible in CA-based intensive production systems

• Improve input efficiency & address climate change

• CA element of best practices but knowledge intensive requiring learning support & common action

• Need for harmonization/mainstreaming - FAO & global stakeholders have a role to play – CA-CoP platform
And, the message, once understood, even makes people dance!

Thank you for your attention
Green house gas emissions and climate change:
• Agriculture as driver
• Means and potential for mitigation
• Adaptation

• Conclusions: why should we act
World GHG Emissions Flow Chart

**Sector**
- Transportation: 13.6%
- Electricity & Heat: 24.8%
- Other Fuel Combustion: 9.0%
- Industry: 10.4%
- Fugitive Emissions: 3.9%
- Industrial Processes: 3.4%
- Land Use Change: 18.2%
- Agriculture: 13.5%
- Waste: 3.6%

**End Use/Activity**
- Road: 9.9%
- Rail, Ship, & Other Transport: 2.3%
- Residential Buildings: 9.9%
- Commercial Buildings: 5.4%
- Unallocated Fuel Combustion: 3.5%
- Iron & Steel: 3.2%
- Cement: 3.8%
- Other Industry: 5.0%
- T&D Losses: 1.9%
- Coal Mining: 1.4%
- Oil/Gas Extraction, Refining & Processing: 6.3%
- Deforestation: 18.3%
- Afforestation: -1.5%
- Reforestation: -0.5%
- Harvest/Management: 2.8%
- Other: -0.6%

**Gas**
- Methane (CH₄): 14%
- Nitrous Oxide (N₂O): 9%
- Carbon Dioxide (CO₂): 77%

HFCs, PFCs, SF₆: 1%

Sources & Notes: All data is for 2000. All calculations are based on CO₂ equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41,700 MTCO₂ equivalent. Land use change included both emissions and absorptions; see Chapter 14. See Appendix 2 for detailed description of sector and end use/activity definitions, as well as data sources. Dotted lines represent flows of less than 0.1% of total GHG emissions.
Greenhouse gas emissions:

Carbon Dioxide is the most important GHG
Other GHG (Methane, Nitrous Oxide) more powerful
Still 77% of total GHG in CO2 equivalent is due to CO2
Agricultural land use contributes 32% of all GHG:
  24% of all CO2
  61% of all CH4 and N2O
The major largest components are:
  Deforestation: 18.3%
  Nitrogen emissions from soils: 6%
  Methane from livestock: 5%
Agriculture mitigating climate change

Globally 5 bill ha (4.109) under agriculture
(= 40% of total land)
3% of this CEJA members
Significant impact on climate change
Potential C-capturing 0.25-2.5 bill t/year
Additionally emission reductions by 50-60%
Agriculture mitigating climate change options for emission reduction: no-tillage farming:

- 60% reduction in fuel
- 20% reduction in fertilizer/pesticides
- 50% reduction in machinery
- C-sequestration 0.05-0.25 t.ha⁻¹.y⁻¹
- no burning, no CO2 release
Agriculture mitigating climate change options for emission reduction:

methane:
  aerobic rice cultivation
  change in livestock diet (grazing)

nitrous oxides:
  change in N-fertilizer management
  change in irrigation practice
Advantages for the farm:
• 50% labour saving
• 70% fuel saving
• 50% saving in machine capital (tractors)
• 40% smaller tractors
• 3-fold lifetime of tractors

as well as:
• high and stable yields
• less climate risk
• higher profit
Conservation Agriculture

Soil Organic Matter = Drought Resistance

Action of Soil Biota

High Soil Organic Matter

Biological Tillage

Mechanical Tillage

Conventional Agriculture

Zero Tillage

adaptation

low soil organic matter