The role of conservation agriculture and associated soil-based technologies in achieving CGIAR system-level outcomes:
Announcing a strategic study and scientific workshop

INDEPENDENT SCIENCE & PARTNERSHIP COUNCIL
CGIAR

From ISPC Chair, Professor Ken Cassman, 17th April 2012

The Independent Science and Partnership Council (ISPC) of the CGIAR is launching an independent strategic study examining the evidence base for conservation agriculture and associated soil-based technologies in achieving the system-level outcomes of the new CGIAR system.

The study will comprise several elements:

- Several commissioned papers on important issues, by independent scientists and economists
- Scientific workshop of invited experts: approximately 40 people, with a mix of CGIAR and non-CGIAR scientists, to be held 15th and 16th October 2012 (venue to be confirmed)
- Open competitive call for papers for up to four scientists from within the CGIAR, with travel grants of $3,000 each per accepted paper
- A special issue of a high-quality academic journal in early 2013

This is a brief background paper describing the motivation for the study, its objectives, and outlining a workplan. Contact James Stevenson (ISPC Secretariat, FAO, Rome: james.stevenson@fao.org) for more information, or go to the ISPC website (www.sciencecouncil.cgiar.org)

Introduction

Tillage is the mechanical disturbance of the soil (through plowing, cultivation or digging) and has been used by farmers since the first settled agricultural production systems tens of thousands of years ago (Lal, 2009). There are a number of good reasons for tilling the soil: it incorporates weeds, fertilizers and manure added to the soil, and previous crop residues; allows preparation of a seedbed to facilitate seed placement at proper depth for uniform germination; helps aerate the soil, which in turn helps release nutrients from organic matter in forms available to plants; controls several soil and residue borne diseases and pests through residue burial; provides compaction relief (perhaps temporarily) when compaction can restrict roots and water penetration; is aesthetically pleasing in terms of look and smell (Hobbs, 2007). However, it is also well-established that there can be negative impacts of excessive or inappropriate tillage practices (as summarized in fig. 1 below).

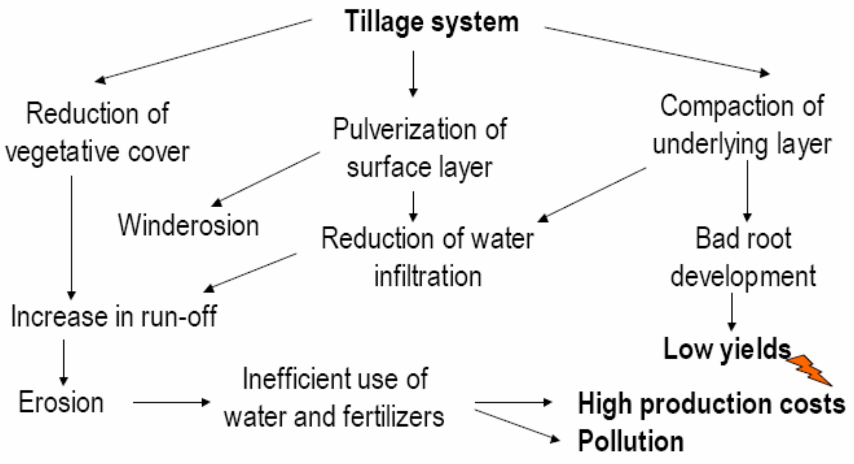

Fig.1 – Negative impacts of inappropriate tillage practices (Hobbs, 2007)

Conservation agriculture (hereon CA) is defined as a package of agronomic practices that includes: a) reduced or eliminated mechanical soil disturbance; b) soil cover with crop residues; and c) diversification of crop species grown in sequences and/or associations (FAO, 2007; Friedrich, Derpsch and Kassam, 2011). The primary rationale for this combination of practices is that it protects the natural resource base for agriculture (e.g. preventing soil erosion) thereby contributing to maintenance of long-run agricultural productivity. A range of secondary benefits, to farmers (e.g. cost-savings from reduced fuel costs), and to the global environment (e.g. reduced emissions of greenhouse gas [GHG] emissions; reduction in irrigation water use), are also suggested by CA advocates.

CA is clearly a promising option for many farmers, and has been adopted as a package on an estimated 124 M ha globally (Friedrich, Derpsch and Kassam, 2011), but particularly in the United States (27 Mha), Brazil (26 Mha), Argentina (26 Mha), Australia (17 Mha) and Canada (14 Mha), which together represent 87% of current total global adoption of CA. Advocates point out that such widespread adoption, albeit concentrated in a limited number of countries, must indicate that adoption of CA is privately profitable for many farmers, and given putative environmental benefits, CA is proposed to be widely applicable to areas and regions where it is not currently practiced. However, there remains substantial uncertainty and controversy within the scientific literature regarding potential benefits of CA adoption (to farmers, to the natural resource base for agriculture, and to the climate) for different crops in different agro-ecosystems[1], and in different institutional and livelihood contexts, and parts of this debate have been played out in recent conferences and in the academic literature. We believe that there is substantial scope for, and value to be had from, an impartial review of these issues from multiple disciplinary perspectives – agronomic, economic and ecological.

Conservation agriculture in the newly reformed CGIAR system

The CGIAR is making a considerable commitment to research on conservation agriculture over the coming years, through the new set of CGIAR Research Programs (CRPs) as well as CGIAR center involvement in a number of other significant multi-partner projects. The CRPs on the three major cereals (3.1 on wheat; 3.2 on maize; and 3.3 rice), all have themes related to conservation agriculture. By implication, CIMMYT and IRRI appear to have greatest investment within the CGIAR. However, these cereal CRPs (3.1, 3.2, 3.3) **all** propose collaboration with CRP 2 (Policies, markets and institutions) on institutions and incentives for producers relating to the adoption of CA technologies, and with CRP 5 (Water, land and ecosystems) and CRP 7 (on climate change, agriculture and food Security) on monitoring the environmental impacts that result from adoption of CA technologies. CA research in the systems CRPs is currently not well defined due to current state of development of these programs but include some research questions about appropriateness of CA to the research hubs they propose. The System-wide Livestock Program is also working on the issue of conflicting uses for crop residues. Annex 1 of this document summarizes the main CA content in the new CRP portfolio.

In addition to the research portfolios wrapped up in the CRPs, there are bilaterally-funded research projects that represent significant research efforts (such as the EU-funded CA2Africa project[2], led by CIRAD, with the involvement of CIAT, CIMMYT and ICARDA; and the ACIAR-funded SIMLESA project[3], led by CIMMYT, and working with ICRISAT).

Given this spread, there is a timely opportunity to better understand the basis for controversies concerning the relevance of CA to resource-poor farmers in developing countries, and to identify ways in which collaboration amongst these projects could be strengthened.

[1] An agroecosystem is defined by the spatial and temporal pattern of crops over time and space, within an agroecological zone defined by climate, soil properties, and whether crops are grown with irrigation or rainfall.

[2] http://ca2africa.cirad.fr/ - CA2AFRICA stands for: Conservation Agriculture in Africa: Analysing and FoRseeing its Impact – Comprehending its Adoption

[3] http://simlesa.cimmyt.org/ - SIMLESA stands for: Sustainable Intensification of Maize-Legume Systems for food security in eastern and southern Africa

Commissioned papers on the controversies, and associated research priorities, regarding conservation agriculture

There has been a significant boom in the number of academic papers published on the topic of conservation agriculture since around 2009. This literature includes a number of controversies relating to the adoption and impact of conservation agriculture approaches in Africa and South Asia. The 11th Congress of the European Society of Agronomy in Montpellier, August 2010, included a discussion session on the topic of whether conservation agriculture is suitable for smallholder farmers in Africa and attempted to draw out the main aspects of a research agenda. The outcomes of these discussions are summarized in the paper by Giller et al. (2011).

Giller et al. identify three scales at which important research questions come up: field level (in teasing apart of the CA "package" to understand what is gained under different circumstances); farm / village / regional levels (understanding CA in the context of people's lives and livelihoods); and at the level of the innovation process (institutional arrangements to support and monitor the adoption of the technology).

We use this scheme as inspiration in proposing the commissioning papers on the following topics.

a) Data on the extent of adoption of conservation agriculture and its constituent components

How widespread is the adoption of conservation agriculture practices in Africa and South Asia? How credible are the existing estimates? What data is available on each of three components of conservation agriculture (zero-tillage; continuous residue mulch or crop cover; crop rotation)? What kinds of methodological and institutional innovation could be developed to track adoption more efficiently in future?

There is considerable disagreement regarding the potential for widespread adoption in Africa and South Asia of a knowledge-intensive technology such as CA. This is compounded by the methodological difficulties of tracking adoption over time. So we are faced with an important issue for which there is limited data and considerable uncertainty.

Conservation agriculture advocates at FAO (Friedrich, Derpsch and Kassam, 2011) have recently compiled a global overview based on their estimates of adoption of the entire CA package. Adoption of component technologies was not considered. However, in our study, not only are we interested in the adoption and impact of CA as a whole package, but we also want to investigate the adoption and impact of the three individual CA components as single management practices. Indeed the codification of CA as a standardized package has been criticized (Giller et al, 2009) as a reason for low adoption in sub-Saharan Africa and South Asia.

Use of remote sensing for monitoring tillage intensity is an innovation proven to be robust in parts of the US. Potential application of this approach to other countries could be explored, within constraints imposed by Landsat bands and availability of data from the Hyperion spectrometer orbiting the earth (Daughtry et al, 2006). Other methods for reporting adoption based on sample surveys, machinery suppliers sales etc, will also be explored.

Other important papers for this review will include: Lyon et al (2004); Knowler and Bradshaw (2007); Kassam et al (2009); Wang et al (2010); He et al (2010); Kirkegaard (2011); Erenstein and Laxmi (2008); Erenstein and Farooq (2009)

b) Understanding the processes of adoption

What are the barriers to adoption of conservation agriculture in different farming systems? How are these barriers conditioned by agro-ecological zone and/or socio-economic contexts? What evidence is there that these barriers overcome? What kinds of institutional arrangements are most effective at facilitating the process of adoption of conservation agriculture? Where has conservation agriculture been "bundled" with aid projects offering inputs (e.g. fertilizers, seeds, tools)?

There are circumstances under which there is little prospect for adoption of the full CA package. For example, crop residues have multiple uses, particularly as livestock feed, and hence may not be economically rational for a farmer to adopt CA and forego benefits from using the crop residue (Valbuena et al, 2012). In situations where crop residue has high value as livestock feed or for other uses, what other soil management options are available to achieve the benefits ascribed to CA?

Knowledge of farmers is a significant barrier this a technology that is not embedded in a specific research output (e.g. seed) but is very knowledge-intensive, and its adoption often only follows from an intensive training in a farmer field school or similar. This could limit widespread adoption of the technology, particularly on small farms with a diversified livelihood portfolio where there could be binding time constraints, or at least high opportunity costs to investing time in learning new agricultural skills. What other forms of information transfer / extension / capacity-building have been attempted and with what level of success?

Other barriers, such as labor requirements / seasonality, insecure land tenure, lack of demand for legumes in the rotation etc will also be reviewed.

Important papers for this review will include: Haggblade and Tembo (2003); Giller et al. (2009); Andersson and Giller (2012); FAO Regional Emergency Office for Southern Africa (2011); Suri (2011); Zeitlin (2010); Todo (2011)

c) Impacts on productivity and profits

Which studies have demonstrated increased farm-level profits under conservation agriculture than conventional production? What are the potential sources of bias in these studies? Beyond on-station trials, which studies have shown an increase in productivity from adoption of conservation agriculture?

These questions introduce farmer and institutional-level effects which mean that results won't necessarily follow expectations from studies carried out under ideal management on-station, or even from the self-selecting farmers that participate in farm-level experiments. The majority of studies on CA adoption show that producers have higher profits under CA than conventional production, mainly due to cost reductions (fewer tractor passes per field, for example). However, few studies rigorously examine the private profitability of adoption for farmers in South Asia and Africa and its impact on yields obtained by adopters. The relationship between conservation agriculture adoption and average yields remains unclear. A number of studies purport to show positive impacts on yield from adoption, when in fact the studies are subject to considerable selection bias, both overt and implicit, and placement bias (see the paper by de Janvry et al 2011, for an explanation of these terms).

There is a large number of studies to be reviewed, including: Haggblade, Tembo and Donovan (2004); Ibragimov (2011); Singh et al (2011); Guto et al (2011); Mazvimavi and Twomlow (2009); Pretty et al (2006, 2007), and critique by Phalan (2007); FAO Regional Emergency Office for Southern Africa (2011); Rusinamhodzi et al (2011);Baudron et al (2011); Farooq et al (2011); Fasinmirin and Reichert (2011); Haggblade and Tembo (2003); Hunt et al (2011); Mupangwa et al (2011); Nkala et al (2011); Oue´draogo (2007); Rockstrom et al (2009); Tsegaye (2010); Verhulst (2011); Wang et al (2011); Farooq et al (2011); Bayala et al (2012); Djigal (2012); Araya et al (2011); Chen et al (2011); Enfors et al (2011); Tang et al (2011); Passioura & Angus (2010); Erkossa (2006); Ladha et al (2003)

d) Impact on ecosystem services

Under what conditions does CA actually help prevent further depletion of the groundwater? Is there a positive impact of conservation agriculture adoption on soil and water quality, carbon sequestration or GHG emissions?

If CA adoption is shown to be a public good, through the generation of on-farm and/or off-farm ecosystem services, then there could be a rationale for subsidizing farmers under a payment for ecosystem services (PES) or carbon credit (CC) scheme. However, the evidence base on the likely ecological benefits from adoption is insufficiently clear to justify this at present. There is a lot of interest in finding this evidence, reflected in the large number relevant studies over the last 5 - 10 years. Again, the causal relationships explored here will ideally take account of farmer-level management effects, as well as measureable heterogeneity in the natural resource base, climate etc in different locations, and consider interactions between spatial scales.

The increased residue cover from CA helps retain soil moisture and can result in a reduction in irrigation water applications (e.g. in rice-wheat systems). However, there are a number of questions about the conditions under which reduced irrigation water use translate to actual water savings or increases in water productivity.

CA is being promoted as a technology that has the potential to sequester carbon and mitigate greenhouse gas (GHG) emissions. A number of papers have attempted to review a broad literature on this issue over the last few years (Corsi et al. 2012; Ogle et al.2012; Grace et al. 2012; Gattinger et al. 2011; Lal 2011; Govaerts et al. 2009). There are two particular methodological concerns with estimates of carbon sequestration in soils under alternative management regimes. First, it is important that the studies examine changes beyond just the topsoil (0-30 cm depth interval) to at least 50 cm, preferably 1 meter (Baker et al, 2007). Second, studies need to account for the decrease in soil bulk density that accompanies an increase in the concentration of soil organic matter in a given soil depth (less soil mass per unit volume, which offsets some of the increase in soil C concentration). Many of the studies in the literature do not follow these principles and so are in effect showing differences in distribution of carbon in the soil profile. However, one area where there is a clear reduction in carbon emissions, at least on a per hectare basis (it remains to be seen whether the productivity-weighted metrics show the same trend), is the reduction in diesel consumption from not tilling the fields, and possibly from reduced rates of pumping of irrigation water.

Soil quality is a broad concept that is difficult to standardize and measure, but a number of studies have cited improvements in soil quality from CA-related technologies. Relevant studies include: Fasinmirin and Reichert (2011); Verhulst (2011); Vlek and Tamene (2009); Farooq et al (2011); Bhawardj et al (2011); Bissett et al (2011); Powlson et al (2011); Gosai et al (2009); Govaerts et al (2007)

In many circumstances, particularly on sloping land in tropical regions, one would expect to find significant soil erosion benefit from adopting the full CA package as the residue dissipates the energy from rainfall and reduces crusting of the soil surface. In this section we hope to compare estimates of these benefits to other forms of soil conservation aiming at the same goals and understand the circumstances under which CA performs best. Relevant papers include: Lahmar et al. (2011); Hobbs and Gaunt; Pansak et al (2008); Blanco-Canqui et al (2009); Chatterjee and Lal (2009)

As Van Groenigen et al (2010) and West (2011) note, metrics for monitoring of GHG-emissions from agricultural production systems should be reported per unit of yield. This would include the potentially lower productivity from adjustments aimed at incorporating environmental objectives. Given the importance of raising agricultural productivity to meet projected increases in demand without increasing agricultural area, this is an important principle that applies to GHG emissions and to water use.

Important papers for this review include: Ahmad et al. (2007); Humphreys et al. (2010); Balwinder-Singh et al (2011 a and b); Davies et al (2010); Ibragimov (2011); Raitzer et al (2010); Rockstrom et al (2009); Verhulst (2011); Makurira et al (2011); Passioura et al (2010); Thierfelder and Wall (2010); Mupangwa et al (2008); Dittert et al (2003); Fasinmirin and Reichert (2011); Vlek and Tamene (2009); Farooq et al (2011); Bhawardj et al (2011); Bissett et al (2011); Powlson et al (2011); Gosai et al (2009); Govaerts et al (2007); Lahmar et al. (2011); Hobbs and Gaunt; Pansak et al (2008); Blanco-Canqui et al (2009); Chatterjee and Lal (2009).

Next steps with the ISPC strategic study

The ISPC is now seeking to commission papers based on the four areas of research priority listed here, and preferably from inter-disciplinary teams of authors. A separate call for papers for CGIAR scientists presenting new work on these issues will be made in May 2012, with up to four travel grants of $3,000 each available to attend the study workshop.

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Annex 1 – Conservation agriculture in the CGIAR Research Programs (2011 onwards)

CRP	**Main CA content** (all page numbers relate to the most recent version of the proposal document)
1.1 (Dryland systems)	Discusses how the CA principles are well-known but that their potential in dryland areas has not been realized, and that there are significant trade-offs regarding residue management and biomass use.
1.2 (Humidtropics)	Discusses how biomass trade-offs need to be managed and proposes building on the work in the system-wide livestock program for analyzing the livelihood implications of alternative uses for biomass. p. 52
1.3 (Aquatic agricultural systems)	CA is mentioned in research questions in Cambodia, and in hypotheses and specific research questions in Bangladesh. In addition they cite Rockstrom et al's paper that details how partnership among farmers, NARS and ARIs to promote CA approaches in semi-arid East Africa were successful when farmers shifted the objectives of the research from a focus on minimum tillage (the researchers' interest) to improved rainwater harvesting, which was their primary concern.
2 (Policies, markets and institutions)	CA is central to two Research Activities: "Policies and strategies that sustainably increase agricultural productivity along the land-water-energy-food nexus"; and, "Policies and strategies that enable and support the delivery and adoption of more sustainable agricultural practices"
3.1 (Wheat)	3 Strategic Initiatives (SIs) with significant CA content: SI 1 (Technology targeting for greater impact); SI 2 (Sustainable wheat-based systems); and SI 3 (Nutrient and water use efficiency). Together, these parts of the CRP represent 18% of the CRP as a whole, or $41.5 million over 2011-13 (if fully funded).
3.2 (Maize)[4]	CA is central to the research questions in SI1 on Socioeonomics and to the activities described in SI2 on Sustainable intensification and income opportunities for the poor. Quotes the Giller et al 2009 paper in the context of how systems need to be adapted to particular farming contexts rather than imported as a package.
3.3 (GRiSP)	Research theme 2 "Accelerating the development, delivery, and adoption of improved rice varieties" includes the first breeding programs for direct-seeding and conservation agriculture. The Rice-Wheat Consortium (RWC) and the Irrigated Rice Research Consortium (IRRC) developed technologies based on CA principles applicable for the South Asia context (laser leveling, residue management, intercropping, reduced tillage, and direct seeding). Since 2009, IRRI has been leading the Cereal Systems Initiative for South Asia (CSISA) on behalf of a number of CGIAR centers and partners. Research theme 3: "Ecological and sustainable management of rice-based production systems" also has a significant research effort devoted to CA principles. Based on CIRAD's experience of long-term monitoring in Madagascar, a new long-term experimental platform will be established in West Africa for the development of conservation agriculture–based upland rice-cropping systems for this region. P. 105
5 (Land, water and ecosystems)	There are relevant mentions throughout the document of potential linkages between plot-level or farm-level experiment data and basin or landscape level data collection / modeling to examine the impacts on the resource base. (See pages 9, 26, 88, 206-7). A number of interesting ideas are discussed regarding the use of new technologies in improving the evidence base for land and water management.
7 (Climate change, agriculture and food security)	In general, much of the research themes 2 (Adaptation) and 3 (Mitigation) are potentially relevant. Specific joint activities are planned in the targeted regions sites with CRP1 and CRP3 (e.g., work in the Brahmaputra–Ganges–Megna focus region of CRP1 and CRP3 will be integrated with CRP7 work in IGP). Box 1 suggests how CRP1 and CRP7 can interact in terms of field testing options. Similarly, technological options and practices developed in CRP3, CRP5 and CRP6 will be selected for testing in the context of integrated adaptation-mitigation strategies, through co-financing.

[4] Note that CIMMYT has a very significant research and extension portfolio on CA specific to Mexico, through major bilateral funding from the Mexican government.