

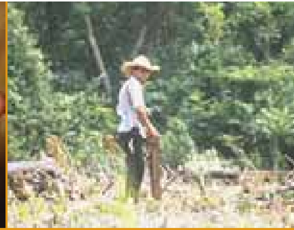


Integrated Crop Management Vol. 6 – 2008

An international technical workshop
Investing in sustainable crop intensification
The case for improving soil health

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An international technical workshop
Investing in sustainable crop intensification:
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FAO, Rome: 22-24 July 2008

PLANT PRODUCTION AND PROTECTION DIVISION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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FOREWORD

For over 2000 years farmers have believed that they must plough to get a good crop. But the more often the land is ploughed, the faster it loses crucial organic matter and the biotic activity it supports. As organic matter content falls, soils become capped and less porous, losing their ability to absorb and retain water – and this has two bad effects: first, there is less water to support crop growth and the biological activity that is so important for productivity, and second, more water accumulates and moves across the land surface, causing floods and erosion.

Already many farmers, large and small, grow crops in rotation without ploughing, on almost 100 million hectares in countries as diverse as the US, Brazil, Paraguay, Argentina, Kazakhstan, DPR Korea, China, South Africa and Australia. They use the residues of previous crops or of specially grown nitrogen-fixing legumes to create mulches into which seed and fertilizer are drilled directly. This type of no-till farming – or *Conservation Agriculture* as it is now called – is a major component of a greener revolution that will make intensive farming sustainable, cut energy use in food production, decrease agro-chemical contamination of the environment, reduce greenhouse gas emissions, minimize run-off and soil erosion, and improve fresh water supplies.

FAO has been involved through its field programme in the pioneering work on minimum and zero tillage and continues to be active in many countries in all continents in testing, adapting and promoting various approaches to conservation agriculture (CA). The spread over the past 30 years or so of these methods has been significant, but the proportion of global farm land that is managed according to CA principles is still relatively small.

This publication is a report of a Workshop that brought together people from a wide range of institutions - farmers, researchers, extensionists, policy makers, donors – from 40 countries who share a common concern about the non-sustainability of ways in which farm land is now being used and who are convinced that this must change. The Workshop, which was hosted by FAO and the UK Tropical Agriculture Association (TAA), focused on the growing evidence of success in the adoption and spread of CA systems in developing countries in Latin America, Asia and Africa, and on ways of mainstreaming CA principles and practices as a sound basis for increasing productivity while sustaining – and enhancing – soil health, biodiversity and other environmental services. CA-based approaches to sustainable production intensification are highly relevant to the global response to rising food and energy prices, increasing soil and environmental degradation, pervasive rural poverty, climate change and increasing water scarcity.

The consensus of the Workshop was that, using CA, farmers can attain higher levels of productivity and profitability while improving soil health and the environment. The main outcome of the Workshop is *'A Framework for Action'*. This presents the joint thinking of the Workshop delegates on actions that would help to empower many more farmers to take up CA, thereby enabling land to be farmed more productively, profitably and sustainably.

Shivaji Pandey
Director
Plant Production and Protection Division
FAO Agriculture Department

ACKNOWLEDGMENTS

The Workshop in Rome was the culmination of a collaborative process in which many individuals and organizations participated over several months to ensure its success. Institutions that helped to plan and organize the Workshop event included: TAA, FAO, UNEP, FARA, ICRAF, ILRI, TSBF-CIAT, CIRAD, ACT and KARI. They all deserve special acknowledgment and thanks for their unwavering technical support and for providing working facilities in Rome, Nairobi and the UK during the planning phase.

FAO and FARA underwrote the basic cost of the Workshop and provided funds to cover the cost of speakers from Latin America, Asia and Africa. This support was supplemented by a contribution from the Bill & Melinda Gates Foundation to cover some of the planning costs, and from GFAR to cover additional participants from the developing regions. All remaining participants were self-funded or sponsored by their respective institutions.

FAO's technical support to the Workshop process and its international connections with the Conservation Agriculture constituency were invaluable to the success of the Workshop as was its role as host. FAO's various technical contributions were competently handled by Theodor Friedrich, Eric Kueneman and Josef Kienzle, with support from Peter Kenmore, Parviz Koohafkan, Sally Bunning, Kevin Gallagher and Dominique Lantieri. Without their moral and technical support and their cooperation, the Workshop event would not have happened. Their professionalism and commitment towards sustainable production intensification and their role in FAO in popularizing Conservation Agriculture as a way forward in the developing regions has been truly exceptional.

FARA's moral, technical and sponsorship support provided a special encouragement to the Workshop process. The participation of Monty Jones and Adewale Adekunle in the Workshop planning process and FARA's administrative support through Victor Keraro and Marie Golie all contributed to the Workshop's effectiveness and success.

TAA's leading role in initiating and catalyzing the Workshop process from its very beginning, on the issues related to improved soil management, deserves to be acknowledged. Very special thanks must go to Amir Kassam, Francis Shaxson, Andrew Bennett and Andrew MacMillan from TAA for their dedicated and unstinting support to the cause, and for their help with planning the meeting's Agenda and with the running of the Workshop in Rome.

The planning process also gained a great deal from many colleagues: the contributions from the following are specifically acknowledged: Don Doering (Bill & Melina Gates Foundation), Frank Place and Dennis Garrity (ICRAF), Denis Depommier and Francis Forest (CIRAD), Adewale Adekunle (FARA), Patrick Gicheru (KARI), Reynolds Shula (ACT), Carlos Sere (ILRI), Stephen Twomlow (ICRISAT), Patrick Wall (CIMMYT), Andre Bationo (TSBF-CIAT) and Akin Adesina (AGRA), Peter Matlon and Ruben Puentes (Rockefeller Foundation), Laurence Cockcroft (Gatsby Foundation), John Lynam (Kilimo Trust), John Barrett and Don Howlett (DFID), Marion Cheatle (UNEP), Mark Holderness (GFAR), Sara Scherr (Ecoagriculture Partners), Long Nguyen (IAEA), John Landers (APDC, Brazil), Bob Boddey (EMBRAPA), Richard Harwood (Michigan State University), and Norman Uphoff (CIIFAD, Cornell University).

There are many people who deserve to be thanked for their contribution to the Workshop through their presentation or serving as session chair or convener, or as rapporteurs or as drafting team liaison persons. In fact, as can be seen from the Agenda, some 60% of the participants were directly engaged in one form or another capacity in running the Workshop process in Rome. They all deserve a special expression of appreciation.

Particular thanks are expressed to all the speakers, session chairs and the rapporteurs of day one of the meeting when the evidence of success and lessons learned with Conservation Agriculture from several countries in the developing regions were presented. Thanks are also expressed to the co-conveners of the three Working Groups, Martin Bwalya and Mark Laing (Field Practice & Development), John Dixon and Nuhu Hatibu (Science & Technology), and Norman Uphoff and Richard Mkandawire (Policy and Finance), and to their respective members, for their balanced contributions to the Action Plan. Similarly, special thanks are expressed to Andrew MacMillan for serving as the coordinator of the Working Group for drafting the Action Plan whose members were Doug Wholey, Will Critchley, Rolf Derpsch, Bernard Triomphe, John Ashburner, Des MacGarry, Patrick Wall, Simon Hocombe and Deborah Bossio. Their enthusiasm and commitment to meeting the drafting deadline for the preparation of the final document '*A Framework for Action*' went beyond the call of duty.

The Workshop secretariat in FAO assisted participants with their travel, visa and hotel arrangements, and was ably managed – before, during and after the meeting -- by Chiara Ventura, with support from Francesca Furino.

Grateful thanks go to Amir Kassam, Francis Shaxson and Theodor Friedrich for leading and overseeing all aspects of the Workshop planning and implementation process, and for compiling this Workshop report.

ACRONYMS AND ABBREVIATIONS

AAB	Association of Applied Biologists, UK
AAPRESID	Associación Argentina de Productores de Siembra Directa
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands, Syria
ACT	African Conservation Tillage Network
AGRA	Alliance for a Green Revolution in Africa
APDC	Associação de Plantio Direto no Cerrado, Brazil
BNF	Biological Nitrogen Fixation
CA	Conservation Agriculture
CAADP	Comprehensive African Agricultural Development Programme
CEC	Cation Exchange Capacity
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIIFAD	Cornell International Institute for Food and Agriculture Development
CIMMYT	International Maize and Wheat Improvement Centre
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développment
CoP	Community of Practice
CT	Conservation Tillage
DD	Direct Drilling
DPR	Democratic Peoples' Republic
ECAF	European Conservation Agriculture Federation
EMBRAPA	Empresa Brasileira de Pasquisa Agropecuária
ESAK	Ecole Supérieure dÁgriculture du Kef, Tunisia
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAQs	Frequently Asked Questions
FARA	Forum for Agricultural Research in Africa
FEBRAPDP	Federation of No-Till Farmers of Brazil
FFEM/AFD	French Fund for Global Environment/Agence Française de Développement
FFS	Farmer Field Schools
GAP	Good Agricultural Practices
GFAR	Global Forum for Agriculture Research

GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit, Germany
HYVs	High Yielding Varieties
IAEA	International Atomic Energy Agency
IAPAR	Instituto Agronômico do Paraná, Brazil
ICRAF	International Centre for Agroforestry Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
INIA	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria
INRA	Institut National pour la Recherches Agricoles
ILRI	International Livestock Research Institute
IRAD	Institut de Recherche Agricole pour le Developpement
JSWC	Joural of Soil and Water Conservation
IWMI	International Water Management Institute
KARI	Kenya Agricultural Research Institute
MDGs	Millennium Development Gaols
MoA	Ministry of Agriculture
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
NRM	Natural Resource Management
OM	Organic Matter
PR	Public Relations
R&D	Research & Development
SARD	Sustainable Agriculture and Rural Development
SARI	Selian Agricultural research Institute, Tanzania
SOM	Soil Organic Matter
SWC	Soil and Water Conservation
SWCS	Soil and Water Conservation Society
TA	Tillage Agriculture
TAA	Tropical Agriculture Association, UK
TAFA	Tany sy Fampandrosoana, Madagascar
TSBF	Tropical Soil Biology and Fertility
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization

USA	United States of America
UV	Ultra Violet
WB	World Bank
WOCAT	World Overview of Conservation Approaches and Technologies
WWF	World Wildlife Fund

PART I

SUMMARY

INTRODUCTION

SUMMARY

The present Workshop built on a previous meeting which took place in March 2007 at Newcastle University, UK, entitled:

'The Importance of Improving Soil Conditions for Water, Plant Nutrients and Biological Productivity to Sustain Agricultural Growth under Rising Population Pressure and a Changing Climate'.

Reasons for concern are that, in many situations, current common agricultural practices - notably tillage and other inappropriate land management - have resulted in deterioration of soils that restrict yields, profitability and sustainability of agricultural land uses. These are matters of special concern in the warm/hot sub-tropics and tropics in the face of rising pressures of population growth and the anticipated likely problems associated with climate change.

At the Newcastle meeting participants had considered that a paradigm-shift towards conservation-effective agricultural systems (as exemplified by well-managed crop rotation and mulch-based zero-tillage systems) would be essential if agricultural growth is to be achieved and sustained.

Planning of this second Workshop began immediately after the conclusion of the Newcastle meeting. In the fifteen months between the Workshops, further examples worldwide of good land husbandry practices based on the 'no-till' paradigm mentioned above have come to be grouped together under the generic heading of 'Conservation Agriculture', whose development and spread across the world is actively encouraged by the Food and Agriculture Organization of the United Nations.

Prior to the second Workshop, a technical paper, entitled *'Underpinning Conservation Agriculture's Benefits: the Roots of Soil Health and Function'* was sent to prospective participants. Its chapter-headings are: (1) Introduction - Challenge; (2) Components of soil productivity; (3) Some adverse effects of 'conventional' tillage agriculture; (4) Key features of optimum Conservation Agriculture; (5) Impacts of CA; (6) Hindrances to progress; (7) CA in suboptimal, problem areas; (8) Thinking unconventionally; (9) Key areas for further investigation; (10) Conclusions.

As an introduction to the forthcoming meeting, a short technical note complemented that produced for the first Workshop (see above) with a definition of Soil Health, arising from the biological nature of soils, and emphasizing the requirement to maintain sufficient supply of organic matter as a substrate for biotic activities within soils.

The basic intention of this second Workshop was to discuss, define and propose modalities for 'mainstreaming' CA appropriately into regional, national and even local policies, plans and programmes, so that the improvement and sustainability of livelihoods of both land and people would be encouraged, facilitated and supported as the norm rather than the exception.

Two introductory sessions described the organizational and technical backgrounds of the meeting. These were followed by three sessions of Power-Point presentations of CA examples: from Latin America (Brazil; Paraguay; Argentina); from Asia (China; Kazakhstan; DPR Korea); and from Africa (Tanzania and Kenya; Tunisia; Swaziland; Madagascar; and an overview of emerging lessons from Africa as a whole).

Three sessions were dedicated to discussions in three parallel Working Groups: (1) Science and Technology; (2) Field practice and Development; (3) Policy and Financing. The purpose was to discuss and marshal the information which had been presented, and to provide - to the plenary group and to the team drafting the report on the outcome of the Workshop - an input from each of the special-topic groups under the sub-headings: Principles and Issues; Investors and Opportunities for Investment; Cross-sector Knowledge-brokering; Contributions to an Action Plan.

The results of their discussions and recommendations were presented to, and discussed in plenary sessions, and the agreed compilations transmitted to the Drafting Team. A draft Action Plan was prepared and presented, again in plenary session, for comments by the three subject-matter Working groups. The draft plan was amended accordingly, and the final draft version was then adopted by the participants.

The finalized Action Plan, entitled *'A Framework for Action'*, provides a concise summary of the presentations and discussions, and the recommendations that arose from them, moulded into statements of the central concerns and the characteristics of CA which can effectively address them. Goals and strategies for effective action – both agronomic and organizational – are set out under the main headings: Science and Technology Development; Underpinning Scaling-up of Conservation Agriculture; Creating Supportive Policies, Putting in Place Incentives, and Tapping Resources. Each of these is subdivided into: Strategic Issues - Goals - Priority Actions.

Under the heading 'Next Steps' it records that the Workshop participants recognize the value of joint action and wish to contribute to the emergence of greater and sustainable institutional and human capacities to:

- Acquire, evaluate, share and disseminate accurate, unbiased and diverse **knowledge** about the principles, practices and impacts of conservation agriculture;
- Raise **understanding** in governmental circles, professional organizations and the general public of the benefits, limitations and solutions relating to CA;
- Identify, share, enhance and give more ready access to multidisciplinary **expertise** on CA; and
- Support diverse **initiatives** for research, extension, advocacy and evaluation of CA that can advance the state of the art and the effective application for CA.

Participants wish to establish and sustain a **multi-stakeholder knowledge management system** that will be suited to the needs of diverse users, and in particular of farmers who can benefit from more appropriate and effective CA practices. They wish to set up a system of interlinking web-based system of 'Communities of Practice' with some overarching identity and common purpose, and which will engage a variety of agencies, professional organizations, and publics to acquire mindsets and create programmes more supportive of CA. Possible areas of focus for specific constituent CoPs would be: Knowledge-generation and exchange for CA; Advocacy for CA among the public and decision-takers; Training and information-exchange support for CA initiatives in the field; Education for CA through curriculum improvements in primary and secondary schools, plus enrichment of university and professional education. A Facilitating Group is envisaged to both initiate such a process and prepare both a Policy paper on CA, and an Analytical paper on CA's relative costs and benefits.

At the conclusion of the two-day meeting, the 96 participants from 40 different countries agreed that progress had been made towards putting their agreed Framework for Action into operation.

INTRODUCTION

The present Workshop builds on a previous Workshop which took place in March 2007 at Newcastle University, United Kingdom, entitled:

'The Importance of Improving Soil Conditions for Water,
Plant Nutrients and Biological Productivity
to Sustain Agricultural Growth under Rising Population
Pressure and a Changing Climate'.

The Newcastle Workshop was organized by the Tropical Agriculture Association (TAA) in collaboration with the World Agroforestry Centre (ICRAF), Association of Applied Biologists (AAB) and the Universities of Reading, Newcastle, Nottingham and Durham.

A short background paper, distributed prior to the meeting, set out the reasons for concern that, in many situations, current common agricultural practices have resulted in deterioration of soil qualities that restrict both yields, profitability and sustainability of agricultural land uses, matters of special concern in the tropics and sub-tropics.

The 57 participants, from a range of countries and of national and international institutions, considered the agro-ecologic and socio-economic aspects of sustaining landscapes' capacities to yield vegetation and water. They discussed the implications of three keynote presentations showing experiences with integrated soil-system management in Latin America, Africa and Asia, which were complemented by an overview of other positive advances in the tropical and sub-tropical regions. These showed positive examples of principles and practices of how degradation of land and livelihoods might also be reversed elsewhere.

They considered that a paradigm-shift towards conservation-effective agricultural systems (as exemplified by well-managed mulch-based rotational zero-tillage systems) is essential if agricultural growth is to be achieved and sustained.

Key factors determining sustainability were identified as: (a) biological activity in the soil which, with adequate and ongoing provision of organic materials, is capable of maintaining soils' porosity and productivity on a recurring basis; and (b) decision-making by farm families, which determine their management of the land they rely on for their livelihoods.

To develop these concepts further, Newcastle Workshop participants considered that an innovative, interactive and inter-disciplinary meeting of farmers and their representatives, governments, policy-makers, international aid agencies, private-sector entities, researchers, extension agencies, civil society organizations, and others, should be an important focus for a follow-on international meeting to be held in 2008[1] .

THE ROME WORKSHOP

Planning of the second Workshop began immediately after the conclusion of the Newcastle Workshop. In the fifteen months between the Workshops, further examples worldwide of good land husbandry practices based on the 'no-till' paradigm mentioned above have come to be grouped together under the generic heading of 'Conservation Agriculture' (CA), whose development and spread across the world is actively encouraged by the Food and Agriculture Organization of the United Nations. Although the original intention had been to hold the second Workshop in Nairobi, Kenya, because of public-security concerns it became necessary to change the venue of the Workshop, which was kindly hosted by FAO/UN at its headquarters in Rome.

Prior to the second Workshop, a technical paper, entitled *'Underpinning Conservation Agriculture's Benefits: the Roots of Soil Health and Function'* was sent to prospective participants. Its chapter-headings are: (1) Introduction - Challenge; (2) Components of soil productivity; (3) Some adverse effects of 'conventional' tillage agriculture; (4) Key features of optimum Conservation Agriculture; (5) Impacts of CA; (6) Hindrances to progress; (7) CA in sub-optimal, problem areas; (8) Thinking unconventionally; (9) Key areas for further investigation; (10) Conclusions (see Appendix 1 for the technical paper).

As an introduction to the forthcoming Workshop Agenda, a short note complemented that produced for the first Workshop (see above) with a definition of Soil Health, arising from the biological nature of soils, and emphasizing the requirement to maintain sufficient supply of organic matter as

[1] *Extracts from the: Synopsis of the Workshop entitled: The Importance of Improving Soil Conditions for Water, Plant Nutrients and Biological Productivity to Sustain Agricultural Growth under Rising Population Pressure and a Changing Climate. 30-31 March 2007, Newcastle University, organized by the Tropical Agriculture Association in collaboration with ICRAF, AAB and the universities of Reading, Newcastle, Durham and Nottingham.*

a substrate for biotic activities within soils (see Appendix 2 for the Workshop Technical Background and Agenda).

Also in the fifteen intervening months, public and political concern had been rising on a number of globally-significant topics: notably, rising/high costs of fossil fuels and their impacts on prices of food and other commodities; the ongoing plight of the rural poor, exacerbated by their shortages of food and funds; rising levels of carbon dioxide in the atmosphere and anticipated effects of global warming on growing conditions and water supplies.

It is now increasingly recognized that, as a justification, there is firm evidence from a range of different combinations of agro-ecologic and socio-economic situations that well-applied CA can contribute effectively to addressing among others:

- Increasing pressures to cultivate land which was earlier considered unfit for such purpose;
- Damaging effects of tillage;
- Excessive oxidation of organic matter and release of excess carbon dioxide to the atmosphere;
- Food-insufficiency and/or -insecurity;
- Water-shortages;
- Droughts, soil erosion, floods.

The basic intention of this second Workshop was to discuss, define and propose modalities for 'mainstreaming' CA appropriately into regional and national and even local policies, plans and programmes, so that the improvement and sustainability of livelihoods of both land and people would be encouraged, facilitated and supported as the norm rather than the exception.

WORKSHOP OBJECTIVES

Following recommendations made at the conclusion of initial Workshop at Newcastle University, UK, on 30 and 31 March 2007, the organizers of this Workshop have invited stakeholders concerned with agricultural development in the tropics, subtropics and elsewhere to consider the demonstrated potentials of Conservation Agriculture (CA) to improve soil health, and hence productivity and sustainability, as a basis for crop and agriculture intensification and managing ecosystem services. The Workshop objectives are:

1. To describe the principles of Conservation Agriculture and demonstrate its benefits for farmers and societies to widen attention of potentially-supportive decision-makers in the broad fields of Field Practice & Development; Science & Technology, and Policy & Financing.

2. To discuss, suggest and agree the chief forms of interlinking decisions and action which would provide positive encouragement of, and support to, farmers to make and sustain their transition to beneficial CA systems as most appropriate to their different agro-ecological and socio-economic situations;
3. To pave the way for comparable forums to develop and function at continental, national and local levels;
4. To favour the development of an inter-connected 'Community of Practice' around the subjects pertain to and the benefits deriving from Conservation Agriculture.

WORKSHOP FORMAT

The Rome Workshop comprised the following sessions[2]:

Session I comprised a Welcome speech, and information about the objectives, process, agenda and expected outcome of the Workshop

Session II set the technical scene with a global overview on Soil Health and Conservation Agriculture, based on the two previously-sent background documents (see Appendices 1 and 2).

Session III saw presentations of CA examples from Latin America: Brazil; Paraguay; Argentina.

Session IV, from Asia: China; Kazakhstan; DPR Korea.

Session V, from Africa: Tanzania and Kenya; Tunisia; Swaziland; Madagascar; emerging lessons from Africa.

Sessions VI - VIII were devoted to discussions in three parallel Working Groups –1. Science & Technology; 2. Field Practice & Development; 3. Policy & Financing – and the preparation of their special-subject reports back to the plenary group, each under the sub-headings: Principles and issues; Opportunities for investment, and Investors; Cross-sector Knowledge-brokering; Contribution to an Action Plan.

Sessions IX – X were presentation and discussion of these three reports, and transmission to the Drafting Team of an Action Plan.

[2] A CD of all the PPT presentations is in the inside of the back cover

Session XI saw the presentation of the first draft of the Action Plan.

Session XII: The draft Action Plan was discussed by each Working Group from its particular perspective.

Session XIII: Each Working Group submitted its comments on the draft Action Plan to the plenary, and passed them on to the Drafting Team for final adjustment of the Action Plan.

Session XIV was a viewing of technical posters and other publications, while the rafting Team completed its work.

Session XV: Adoption of the Action Plan, and Closure of Workshop.

PART II

Sessions I - XV

SESSION I
Background to the workshop: Objectives of the workshop, process and agenda, expected outcome

I. OPENING SPEECH

by **James Butler**, Deputy Director General, FAO

The US 'Dustbowl' events in the 1930s, and comparable soil destruction across the Chernozem soils of Central Asia in subsequent decades, followed by erosion are seen as evidence of the effects of loss of adequate cover to the soil and the destruction of soil structure and thus of its porosity, resulting in disastrous decline in the productivity of those lands. As present and future demands for the products of the land increase, and food prices rise, intensification of common systems of agriculture continue to result in declines in soil's inherent productive capacities, yet remarkably little is being done as yet to promote alternative, truly sustainable systems of plant production based on improving health of soils on which their lasting success depend. Raising levels of organic matter in soils is a key both to the reversal of downward trends in productivity, to stimulating key biological processes in the soil, to enabling safe intensification of land uses, and to ensuring their sustainability into the future. The application of the principles of '*Conservation Agriculture*' – with whose development and spread FAO has already become deeply involved – indicate the way forward. He expressed optimism about the outcome of the meeting because (a) the meeting creates opportunities for addressing the issues from a multi-disciplinary perspective; (b) it aims to consolidate such partnerships by creating a 'community of practice'; and (c) it is taking place at a time when the world has been jolted out of complacency over its ability to feed itself adequately in future and many people will be interested in the findings.

II. THE CASE FOR IMPROVING SOIL HEALTH

by **Francis Shaxson** [*PPT #1 - Background*]

Soil biological processes are 'energizers' of the interactions between the four components of soil productivity – physical, chemical, biological and hydrological. This provides soils' 'self-recuperation capacity' with respect to soil porosity, of vital significance to maintaining catchments' capacities for providing both plant materials and water together. Soils' productive capacities degrade when the rate of damage exceed their inherent rates of self-recuperation. Well-managed Conservation Agriculture systems achieve this two-part reversal of trend by improving soil health through minimal/zero-tillage, thereby minimizing undesirable rates of oxidation of organic matter, and by adding organic matter faster than it is being lost, up to equilibrium state. For the undertaking of production to satisfy their needs, farmers make rational decisions within the 'envelope' that surrounds them, whose margins are determined by the interplay of potentials which the farmer can make use of and the hindrances which confront their best expression. Given the wide variety of constraints among so many different agro-ecologic and socio-economic situations across the world, the challenge is to determine, in each situation, how the needs of the land, the motivations and skills of people, and the resources available can be brought into productive balance on a sustainable basis for intensified production. The purpose of the Workshop is to provide an opportunity for different stakeholders concerned with agricultural development to examine and consider the implications of samples of evidence - from different regions - of the potential of Conservation Agriculture to improve and maintain: soil health, stable productivity, ecosystems services, and people's livelihoods. The meeting was structured to (a) provide illustrations of practices and principles of CA; (b) enable discussions, suggestions and agreements on the chief forms of interlinking decisions which can further the understanding, development and spread of CA; (c) pave the way for comparable forums to develop at continental, national and local levels.

SESSION II

Global overview on soil health and conservation agriculture – setting the scene

by Theodor Friedrich [*PPT #2 - Soil Health and CA*]

Summary of the main document: 'Underpinning conservation agriculture's benefits: The roots of soil health and function'
(by Francis Shaxson, Amir Kassam, Theodor Friedrich, Bob Boddey & Adewale Adekunle)

Introduction

- General background: increased demand for plant products, land degradation and soil erosion, increased signals for overcharge on water resources.
- Challenge: Reverse trend of non-sustainable production while increasing production.

Components of soil productivity

- Soil productivity (vs. fertility) consists of following components: physical: architecture – pore structure; hydrological: moisture storage and infiltration; chemical: nutrients, CEC, dynamics; Biologic: soil life and non living fractions.
- Conventional agriculture is characterized by regular tillage, clean seedbed causing following effects: removal of cover, disruption of pores, destruction of structure, loss of organic matter.
- Consequences of low Soil Organic Matter are: less efficiency of mineral fertilizer - "the crops have become 'addicted' to fertilizers"; water loss as runoff; soil loss as sediment; loss of seeds, fertilizer and pesticides through erosion and leaching; less capacity to capture and slowly release water and nutrients; falling input efficiency; declining yields; reduced resilience; reduced sustainability, *degraded biotic activity, reduced soil-porosity recuperation..*
- Key features of optimum CA are the combination of continuous zero tillage, permanent soil cover and crop rotations. This combination has

become known as Conservation Agriculture, simulating forest floor conditions.
- Main feature is soil organic matter, consisting of living and non-living fractions with multiple functions, such as retaining nutrients, CEC, transforming soil components, release of organic acids, structure building, creation of macro pores.
- Advantages for the farmer through applying CA are in improved farmer's livelihood : for mechanized farmers: less machinery, 70% fuel saving; for smallholder farmers: potential advantages 50% labour saving, less drudgery, stable yields, food security; all this resulting in better livelihood/income.
- Advantages of CA for communities address public goods: less pesticide use (-20%), less pollution, lower cost for water treatment, more stable river flows, lower road/waterway maintenance.
- Global advantages are improvements of groundwater and soil resources, biodiversity and mitigation of climate change.

Hindrances to progress

- Hindrances for acceptance of CA: adaptation to agro-ecologies, nutrient depleted soils, land cultivation, tillage as base technique, challenges of tropical climate
- Intellectual barriers: erosion seen as cause of problem, fertility limited to nutrients, belief in the need for tillage, erosion taken as unavoidable, attempts to copy green revolution
- Suboptimal conditions for introduction of CA are no reason for not introducing CA; continuing with tillage would be worse; specific suboptimal conditions and their problems are: arid climates: soil cover establishment; subsistence farmers: crop rotations (maize); humid tropics: P-deficiency
- Important is to keep carbon gains and avoid tillage: one tillage operation can oxidize a year's carbon gain; avoid compaction; if necessary, break only seed lines, apply controlled traffic, in very special cases use strip tillage; other examples of new way of thinking are: "Soil erosion is not caused by deforestation, overgrazing, excessive cultivation" but by loss of SOM, porosity, plant cover; "Soil to be treated more as biological than a geological entity" leading to the concept of SOIL HEALTH; CA should not be "taught to" but developed by farmers (clubs, FFS)

Areas for further investigations

- General points for investigations: resistant reserves of SOM, effect of different OM inputs, indicators for soil health, livestock integration, mechanisms to support CA adoption, quantification of CO2 flux rates.

Site specific points for investigation: effects of crop rotations/cover crops, weed management, pest management, fertilization rates, economic values of services (water), monitoring of changes and effects

Conclusions:

- Important role of SOM for soils
- Response: CA reverses negative trend
- A new "green/blue revolution": productivity and sustainability
- Soil to be understood as living entity
- Replace the tillage presumption
- CA as example for good land husbandry: soil health, production intensification and ecosystem service
- CA is NOT a PANACEA, i.e. it is not a sufficient, but it is a NECESSARY CONDITION for sustainable land husbandry.

SESSION III
Conservation Agriculture cases from Latin America

I. BRAZIL

Conservation agriculture: No-tillage including cover crops and crop rotation in Brazil

by **Ademir Calegari** [*PPT #3 - Brazil*]

After dramatic effects of soil erosion following un-planned expansion of agriculture across the country, it was found hat mechanical soil conservation practices were insufficient to control the problem. From a few hectares under no-till in the early 1970s, the spread of fully-developed CA has now spread to some 26 million ha, with 5.7 million ha in Paraná State alone. Adequate systems comprise minimal/no-tillage plus cover crops and rotations. In a non-conventional paradigm, these orderly systems have resulted in higher storage of water in the soil profile, reduced surface evaporation of water, and related hydrologic benefits, raised yields per ha of many crops, improved weed control, better efficiency of use of inputs and energy inputs, and showing themselves to be both economically feasible and ecologically sustainable. A range of cover-crops in the rotations are used to maintain soil cover, provide additional fodder, and augment organic matter, at the same time as fulfilling multiple agronomic, ecological or economic functions simultaneously. Soil organic matter levels are consistently found to be a keystone soil quality indicator, inextricably linked to other physical, chemical and biological soil quality indicators, and an indicator of sustainability. More than fifty percent of total cropped land in Brazil is now estimated to be managed under appropriate CA systems, on the lands of both large-scale and small-scale farmers. Reasons for the latter to favour CA systems include savings in time and labour, control of erosion, higher yields and greater income. The development of associations of farmers interested in CA systems has been crucial in the increase and spread of CA systems in Brazil.

II. PARAGUAY

Experiences with conservation agriculture/No-till in Paraguay

by **Rolf Derpsch** [*PPT #4 - Paraguay*]

CA methods for a wide range of crops have spread from about 20,000 ha in 1992 to 2.2 million ha in 2008 (65% of all agricultural land in Paraguay), among both mechanized medium and large farmers using tractor equipment, and among small-scale farmers with farms of less than 20 ha using hand labour or animal traction. CA has hade significant positive effects on soil conditions, its physical, chemical and biological conditions, resulting in increasing productivity over time; average yields have increased between 1 % and 30%. There have been beneficial effects on soil moisture through continual cover lessening evaporation from the soil surface. Small farmers have commented that they would never go back to the old system, because the reduced work-load and other benefits have improved their livelihoods. Farming sustainability has been improved through these effects and that of minimizing soil erosion. Adaptation, adopting and spread of CA methods has been significantly favoured by many joint activities between the public sector, international aid agencies and the private sector. The nature and se verity of imitations which still limit he extent and rate of spread of CA in Paraguay include: limited relevant research n CA; high cost of advisory coverage of 300,000 small farmers; limited financial and personal capabilities of the Extension (advisory) service; limited support for the spread of CA among small farmers by international aid agencies in some departments. Knowledge is still the most important limiting factor in the spread of CA methods. Needed improvements include more alliances between stakeholders and donors; more research on green manure/cover crops for efficient and cost-effective weed control, N-fixation, soil loosening etc.

III. ARGENTINA

Environmental and productive quality management in conservation agriculture

by **Santiago Lorenzatti** [*PPT #5 - Argentina*]

There are currently an estimated 15-16 million ha of CA in Argentina. It has been found that it presents a real and concrete alternative to tillage agriculture that has proved to be more ecologically benign, maintaining yields and reducing costs without impacting adversely on the environment. Its optimum expression is seen when it includes not only no-till, rotations and cover crops but also integrated insect pest and disease management, nutrients restoration and rational and professional use of external supplies. It has been shown that the agronomic ecosystems are no longer vulnerable and productive areas have been extended without experiencing some common risks. Soil productivity has increased due to better chemical and physical aspects of fertility and more efficient water economy. It had reduced fossil fuel consumption, lessened carbon dioxide emissions due to the absence of tillage, and increased soil organic matter, favouring carbon sequestration. In this context, the farmers' organization AAPRESID is developing an initiative to develop an Environmental and Productive Quality Management System which can offer certification. This involves the development of a Good Management Practices Protocol and the use and recoding of scientifically-based indicators that enable measuring the impact of the agriculture on the environment. The certification will be of the process, not the product. Among other aspects, it is anticipated that this will bring producers and consumers closer together, and generate new leverage for the creation and growth of new service companies.

SESSION IV
Conservation Agriculture cases from Asia

I. CHINA

Conservation Agriculture Development in China

by **Gao Huanwen** [*PPT #6 - China*]

China is characterized by a large land area, high population, and mostly small family farms. Single crops per year are found in areas of <500 mm rainfall in the north, through double cropping on irrigated land in the central areas with rainfall 600-800 mm, and in the south, paddy fields with multiple cropping under rainfall of > 1000 mm. Studies of Conservation Tillage (sic) began in the 1970s, with human or animal power; investigations with powered equipment began in 1991. There are currently about 3.3 million ha of CT in China: 1.4 million ha in the north, using light tractors and passive seeders; 0.6 million ha in the centre, using mid-sized tractors and power-driven no-till seeders; in the south there is rice direct-seeding, no-till transplanting mainly using hand tools or animal power. It is recognized that it would be desirable to minimize soil disturbance, have cover crops, and follow rotations in all situations. However, the small size of farms, lack of sufficient appropriate equipment and, as yet, limited research and experience of managing combinations of seeds, fertilizers, water, cover crops etc. for true CA in the varied ecozones of the country, plus an extension system not yet oriented to such systems, are factors hindering CA's wider spread. It would be desirable to have an 'ecology subsidy mechanism' which encouraged farmers to make the transformation, making use of CA-dedicated research and effective oriented extension, and also offering the possibility for farmers to acquire suitable equipment initially at reduced cost. In the meantime, progress is being made in learning how, first, to reduce tillage, then to develop rotations and further increase soil cover, and move towards ideal situations step by step as different agro-ecologic and socio-economic conditions permit.

II. KAZAKHSTAN

Improvement of soil and water management in Kazakhstan: Conservation agriculture for wheat production and crop diversification

by **Murat Karabayev** [*PPT #7 - Kazakhstan*]

Kazakhstan has a continental climate, with hot summers and sub-zero winters, and mean annual rainfall (varying from north o south, between 400-250mm. A major crop is wheat, whose yields have generally ranged between 0.9-1.1 t/ha. Soil moisture inadequacy is a significant factor limiting yields. In addition, water and wind erosion is widespread. Concerns about drought, soil salinity and weed infestation are increasing, while decreasing soil fertility is evidenced by loss of topsoil organic matter. After initial work in 2000, the area under zero/minimal tillage and direct sowing has been rising rapidly from zero to around 600,000 ha in 2008, in both irrigated and no-irrigated conditions. Yield benefits in rainfed areas derive much from improved soil moisture conditions, related to better infiltration of water derived from both rainfall and winter snowfall. An attraction to farmers is also the reduction in costs, and the better timeliness of sowing due to reduced energy-use. In irrigated conditions, CA methodology applied on permanent raised beds has proved very efficient. Experience to date shows beneficial changes in both the physiological characteristics of individual plants and in overall yields. Good information has been amassed on the comparative economics of wheat-growing under tillage and CA systems of production. Key aspect still requiring attention include: weed control; economically viable crop rotations and diversification of production; plant nutrition under CA conditions with respect not only to grain yields alone but also generation of plant biomass usable to raise organic-matter levels in the soil; processing and marketing of newly-introduced crops; building scientific and technical capacity, teaching new technologies and agricultural methodologies, providing appropriate training courses at all levels, providing suitable consulting services, and building public awareness of these up-to-date farming systems.

III. DPR KOREA

Introduction of conservation agriculture techniques in DPR Korea

by **Kim Kyong Il and Kim Chol Hun** [*PPT #8 - DPR Korea*]

In DPR Korea, approximately half the arable land is under paddy rice, and half under upland crops. Mean rainfall is 1000-1200 mm annually, of which some

60% falls in July and August. Winter temperatures fall below freezing, while summer temperatures average 24 degrees. The government's fundamental agricultural policy is to provoke a revolution in seeds, crop intensification, and diversification. Since the initial convincing work on CA in 2003 on three cooperative farms, the methods have spread to another 22 farms, and thousands of hectares are at the stage of introductory CA work. The growing awareness and benefits of CA are seen as closely aligning strongly with the government's aims to intensify cropping and make continuous improvements in soil fertility. CA techniques are being applied as: no-till paddy transplanting or no-till direct seeding with mulching; no-till upland crops with direct seeding and mulching; CA potato production (coverage with straw, not soil); maize or paddy direct seeded after green manure crops. Crop residues are retained to provide dense complete soil cover, whether planting is by hand or machine. Progressive annual increases in soil organic matter, in soil inhabiting organisms, and in available N, P and K have been recorded. Yields of main crops have increased by 10% or more, while labour, fuel and time have been saved in the process of production. Now that results and advantages of CA's introduction are clear, it is important to raise interest among policy-makers so that they can formulate appropriate strategies for its further encouragement. Non-farm agricultural staff also should be informed of its advantages and methods, and also traditional farm machinery needs to be replaced by equipment most appropriate to the effective further spread of CA.

SESSION V
Conservation Agriculture cases from Africa

I. AFRICA

Assessing and accompanying CA development in Africa: Emerging lessons

by **Bernard Triomphe, Saidi Mkomwa and Josef Kienzle** [*PPT #9 - Africa*]

Due to the intrinsic complexity of CA as a technical system, and to the many aspects involved in is promotion, understanding and accompanying CA development requires making due use of appropriate conceptual considerations. Firstly, it involves innovation in the farming system, to provide local adaptation, with reference to interlinked biophysical, agronomic, socio-economic and social aspects. Linked to farmers are non-farm agriculturists involved in developing and disseminating knowledge, advising farmers, providing relevant services or shaping local or national policies. Secondly, it involves consideration of innovation pathways – the routes and time as farmers shift from current practices to CA practices. This is a better way of looking at CA than just referring to 'adoption'. Thirdly, it needs to characterize CA as farmers actually adapt, integrate and implement it, and their actual access to knowledge, advice and resources. A final consideration is how to measure CA performance and impact. A series of case-studies were undertaken across Africa in 2005-2006 having regard to these considerations. The first lesson to emerge is that the farmers do not tend to go for permanent no-tillage, but rather go for disturbing the soil periodically. This is clearly better than continuous tillage, and corresponds better with a number of farmers' objectives with regard to management under their local conditions. A second outcome is that many if not most farmers struggle to maintain adequate soil cover. Thirdly, there are good reasons on the one hand for using herbicides under certain conditions, but also other reasons for not using them. A fourth lesson is that the prevalence of a 'project' approach to piloting CA seems to be a major problem, on account of unrealistically short time-frames, discontinuities in strategies and availability of support, and limited lead-time for institutionalizing a proper CA agenda into existing institutions and policies. Pre-eminence is often given to 'demonstrating' CA rather than adapting it in a participatory manner to the local context. In particular, farmers and their associations appear to play a secondary role compared with those of outsiders. Even the principles of Farmer Field Schools are seldom wholly adequate, if only because of its costs and its sensitivity to the qualities and skills of the facilitators. Rather than asking about "How to change farmers' mindset and convince them of the beauty of CA and what wonders it can do for their soils?" we should be asking "What type of CA should be developed, for and with what types of farmers and conditions, with what approach, at what cost with what benefits to farmers and society?". One should accept that eventual success, wherever achievable, will depend on a complex, and relatively slow process which needs to be re-invented and nurtured locally, 'on-the-go', given existing conditions, constraints and opportunities.

II. AFRICA

Enhancing access to CA knowledge and information and partnerships: Experiences of the African Conservation Tillage Network (ACT)

by **Saidi Mkomwa and Josef Kienzle** [*PPT #9 - Africa*]

The ACT is a not-for-profit voluntary membership NGO with offices in Nairobi. It receives funds from many international organizations. The current membership stands at 1200 individuals and institutions from 33 countries. As the earlier 'Green Revolution' model appears to be less than satisfactory for African situations, and food prices and costs of transport rise, a new paradigm "Producing locally for local consumption' seems to be emerging. In this context, CA has the potential to enhance food security through increased and stabilized productivity of soils and crops. Building on indigenous and scientific knowledge, and using innovative equipment designs from fore-runner Brazil, CA is beginning to spread in Africa. But its more rapid spread requires better understanding of: why many farmers 'backed away' from the Green Revolution and reverted to worse conditions than before; the identification and removal of current hindrances to farmers accessing and perfecting available improved practices. ACT aims to facilitate the shift from the common 'input-based approaches' to those better informed by sharing up-to-date knowledge and adaptations. What is lacking is not knowledge but the will to make best use of it. ACT provides web-based support to its members by providing a wide range of information relevant to the use, development and spread of appropriate CA methodology. A reference book on CA for farmers and advisory staff, and case studies, brochures and informative leaflets are produced and distributed. ACT is involved with the World Congresses on Conservation Agriculture, and provides learning-education and training support to Farmer Field Schools curriculum development and adaptation. International tailor-made workshops and training courses have provided many CA graduates scattered throughout Africa who provide a good nucleus for CA expansion. A major challenge is to accelerate and address the issue of curriculum reform at higher education levels so that agricultural colleges preferentially teach CA principles and practices vs. tillage methods. In recognizing farming communities and farmers no only as producers but also as stewards/managers of broader ecosystems, emphasis is now being laced on developing human capital and potentials at the farm level. Networking farming communities can help utilize their strength of togetherness to lobby for and tap into existing resources for micro-credit, insurances and environmental services.iii. Kenya and Tanzania

III. KENYA AND TANZANIA

Conservation Agriculture adoption experiences in East Africa: The case of Kenya and Tanzania

by **Barrack Okoba and Wilfred Mariki** [*PPT #10 - Kenya and Tanzania*]

From 2004, the CA-SARD Project ('Conservation Agriculture for Sustained Rural Development') introduced the concept of CA in rural areas of northern Tanzania and in western and central regions of Kenya, where there was evidence of widespread land degradation, low soil fertility and high soil loss due to poor cover and low organic matter levels. It has the developmental objectives of improving food security and rural livelihoods of small and medium farmers, to be approached through Farmer Field Schools, in which all production constraints are identified and farmers and community leaders are involved in learning about CA. The area covers approximately four agro-ecological zones, from the Upper Highlands to the Lower Midlands across which the climatic conditions correspond with altitudinal gradient in terms of rainfall (400-2200mm/yr.), temperature and soil fertility. The higher is the altitude, the higher the rainfall and the lesser the soil degradation. Through participatory assessments by practising farmers, it is found that the net financial benefits can be higher under CA than under conventional tillage agriculture, particularly because of savings in labour/time, lesser amount and cost of fertilizer required to maintain yields, and reduced energy/fuel costs for tillage and spraying operations. 20 large-scale farmers (>100 ha) operate some aspects of CA on a total 10,000 ha of land, using not-till plus permanent soil cover, but not using crop rotations. 500 medium-scale farmers (10-50 ha) covering approx. 3,000 ha combine no-tillage and crop associations and make efforts to achieve permanent soil cover, despite competition from livestock for fodder. Smallholders (2.5-10 ha) cover about 20,000 ha of land parcels, under mixed cropping systems. They are using a combination of no-till and permanent soil cover using legume cover crops. Though crop rotations are hardly practised, they have been using crop associations. Positive improvements due to the practices used have been quantified for earthworm populations, biomass and grain yields. Feedback from Farmer Field Schools have shown up the following challenges to the adoption of CA: (a) how to integrate livestock and mixed cropping on smallholdings; (b) unavailability or inaccessibility of CA inputs and equipment in local markets; (c) low capacity of local manufacturers of hand/animal-driven CA equipment; (d) how to develop effective CA in semi-arid to arid zones in view of their characteristic environmental limiting factors; (e) lack of supporting policies and implementing institutions.

IV. TUNISIA

Direct drilling in Tunisia is a case of technology transfer

by **Moncef Ben-Hammouda, Khelifa M'hedhbi and Hatem Cheikh M'hamed**
[*PPT #11 - Tunisia*]

In contrast with the conventional mode of diffusion - from small research plots on state research stations, through state development agencies, to farmers ('vertical' transfer) - a 'horizontal' approach to diffusion for spreading CA based on Direct Drilling (CA/DD) is being used in Tunisia). With assistance from CIRAD-France and FFEM/AFD, research is conducted at farm level with farmers using field layouts that can provide statistically-valid data for experiments undertaken at multiple sites and over several years, to compare CA/DD with Conventional Drilling (after tillage). First step extension of the successful research results is done by the farmer on his farm, while strongly assisted by a coordinated multi-disciplinary research team from six technical institutes. Other farmers then willing to undertake their own tests of CA/DD on a small scale are assisted by a specialized crop-production extension team from the public sector. It has been found that other, but sceptical, farmers did not wait long to test for themselves, and some farmers are now recognized by their peers as CA/DD farmer-experts, who can command a fee for their services. As elsewhere, decompaction of soil is a key first step when beginning the process. The Tunisian climate is Mediterranean, characterized by intense, sudden, irregular rainfalls, with large inter-year variability, necessitating different agronomic sequences from one year to another. CA/DD requires a permanent mulching as dry residues of a prior crop or a cover crop, and adapted agronomic sequences, different from static rotations. 'Biological tillage' by soil organisms and by deep-rooted crops becomes the means of maintaining soil porosity, contributing to the overall cost-savings provided by CA/DD. Because of the variable nature of the climate, cropping is opportunistic, using short-season varieties to take advantage of short and irregular periods of adequate soil moisture. Where CA/DD is practised, adequate soil cover has greatly reduced erosion by wind and water, maximizes water-use efficiency and protects soil organisms from direct solar radiation. As noted above, farmer-to-farmer spread of successful CA/DD techniques appears to be occurring, and once they spread more widely, it is anticipated that a state programme could be set up to diffuse the systems among small farmers also.

V. SWAZILAND

Conservation Agriculture in Swaziland

by **James Breen** [*PPT #12 - Swaziland*]

The objective of the project is to provide encouragement of community based natural resource management as a basis for long-term food security amongst resource-poor farmers in Swaziland. Over the last six years, FAO's Emergency Programme in Swaziland has trained a total of around 800 farmers, plus advisory and other staff, and provided limited number of examples of CA equipment suitable for small farmers to use. This process has included a Study Tour to the Potshini Community [CA] Project in South Africa by 17 farmers and two Extension Service staff in 2005, and the selection in 2007 of 85 'Lead Farmers' to facilitate farmer-to-farmer spread There is now a demand from farmers in Shewala for expansion of CA as they recognize it as 'the most sustainable way to produce food'. Jab planters and ox-drawn direct seeders are favoured here. A Field Day was held on June 20th, 2008, attended by 90 farmers and others. Farmers are now requesting more support from NGOs and Extension to implement CA in the areas where it has been in use for some years. It is fervently hoped that this work to expand the spread of CA will be given continuity by a seamless transition of funding for its extension and expansion from its FAO/EP source – which ended in July 2008 - to new sources in the EU and Norway. The most important requirements for the successful implementation of CA in Swaziland *[and, comparably, elsewhere]* include:

(a) An agreed plan to implement CA over the next five years to be drawn up with the cooperation of all stakeholders in Swaziland, including farmers and farmer groups, Extension and Research staff, Government Mechanization Unit staff, related Government Ministries and all relevant private sector firms. This plan should build on experience gained so far in the implementation of CA and should include achievable targets and a good monitoring and evaluation system to identify and deal with field problems as they arise. (b) Active and sustained field research on CA by the Research Department comparing it with conventional agriculture. (c) Policy support to CA and active participation by all members of the National CA Task Force in the sustained promotion of CA. (d) Sustained and practical training for extension and research staff and for farmers, with constant back-up field visits. (e) Adequate supplies of quality seed of maize, sorghum, various legumes and cover crops to ensure maximum biomass yields. (f) Sufficient and affordable supplies of jab planters, ox-drawn planters (possibly on a contractor basis) and tractor-drawn planters. (g) Credit for sustainable procurement of quality, locally adapted seed and other farm inputs thus ensuring good yields. (h) An understanding with livestock owners that crop residues on CA farms will no longer be available free to their stock and that they must make alternative arrangements in this regard. (i) Large scale, sustained, practical training programme for farmers and extension workers. (j) CA to be fully integrated into curriculum at University of Swaziland. (k) Sufficient extension staff (ratio of 1:60 farmers is recommended in Zimbabwe; the ratio in Swaziland is well over 1:1000). (l) Development of well managed side-by-side demonstrations comparing CA with conventional tillage over several years. (m) Need for good farm management and timely planting, weeding and pest/disease control.

VI. MADAGASCAR

Sustainable crop intensification in Madagascar through promoting cropping systems on plant cover

by **Jean-Louis Reboul** [*PPT #13 - Madagascar*]

Since 1990 an NGO ('TAFA') has been in collaboration with IRAD and with CIRAD/Brasil in adapting direct-seeding cropping systems to the diverse agro-climatic and agro-ecologic situations in Madagascar. This has included work on farmers' fields among a wide range of cropping systems and degrees of farming sophistication. Effects have been observed and measured over 15 year, and have shown potentials for improving soil health and function, and people's health. The promotion of these varied systems as a national priority was decided by the Government. The technical successes have provided a basis for AFD and CIRAD to develop an international programme in the 'direct seeding' cropping programmes and some countries in both Africa and

Asia. All the appropriate policies and arrangements to promote adaptation, adoption and spread seem to be have been organized by the Government together with TAFA, built around an original institutional organization – 'The Madagascar Direct Seeding Group' -- a National Diffusion Strategy, much training, and the recent implication of the research community. However, in spite of significant investments, the spread of these technically-validated technologies has amounted to only about 2,500 ha, on which only simple systems seem to be appropriated by the Malagasy farmers. Some hindrances have been identified: (a) insistence by donors on focussing on small farmers alone - among whom change is always slow - exacerbated by the fact of exposure of the technical advisory staff (who have little technical background in the concepts and methods and too little training) to many challenging problems they don't know how to address; (b) complexity of the 'perfect' systems proposed by the scientific community; (c) little or no attention to larger commercially-oriented farmers who could show evidence of the potential benefits, nor involvement of the private sector etc. The type and extent of necessary improvements for wider and more rapid spread include: (i) Strengthening the national operational capacity through experimentation and exposure to field practice, (ii) simplification of the technology for easier understanding by the intended users, (iii) amplification and diversification of training and education activities, and specific training of a large number of Extension staff; (iv) further elaboration f the |national Diffusion Strategy to cover a wide range of users and support agencies, (v) specific assistance to individuals, (vi) support to small farmers by providing appropriate inputs and equipment; (vii) specific support to private sector operators to provide services by large mechanized units; (viii) funding of group activities to improve sustainable land management on communal lands.

SESSIONS VI – XV

Working Groups and Action Plan

Sessions VI-XV were dedicated to discussions in three parallel Working Groups: (1) Science and Technology; (2) Field practice and Development; (3) Policy and Financing. The purpose was to discuss and marshal the information which had been presented, and to provide - to the plenary group and to the team drafting the report on the outcome of the Workshop - an input from each of the special-topic groups under the sub-headings: Principles and Issues; Investors and Opportunities for Investment; Cross-sector Knowledge-brokering; Contributions to an Action Plan.

The results of their discussions and recommendations were presented to, and discussed in plenary sessions, and the agreed compilations transmitted to the Drafting Team. A draft Action Plan was prepared and presented, again in plenary session, for comments by the three subject-matter Working Groups. The draft plan was amended accordingly, and the final draft version was then adopted by the participants.

The finalized Action Plan, entitled 'A Framework for Action', provides a concise summary of the presentations and discussions, and the recommendations that arose from them, moulded into statements of the central concerns and the characteristics of CA which can effectively address them.

The summary of Sessions VI-XV is provided by the "Framework for Action" document adopted by the Workshop, and is reproduced as Part III of this report.

PART III

Investing in sustainable agricultural intensification The role of conservation agriculture

A framework for action

Investing in sustainable agricultural intensification The role of conservation agriculture

A framework for action

This Framework summarises the actions proposed by delegates at a Technical Workshop, held at FAO's offices in Rome in July 2008, with technical support from the Tropical Agricultural Association (TAA-UK). It is intended principally for the use of persons who attended the workshop, so that it can serve as a common point of reference as they engage themselves in follow-up activities. It is also intended to serve as a source of information on Conservation Agriculture (CA) methods and the prospects for expanding their application for those interested in the subject.

Comments on this the Framework are most welcome, as are expressions of interest in participating in the cluster of Communities of Practice (CoP) that are expected to emerge in the coming months.

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Food and Agriculture Organization of the United Nations
Rome, Italy

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PREFACE

This Framework for Action is the outcome of a Technical Workshop, held at FAO headquarters (Rome) in July 2008, entitled: "Investing in Sustainable Crop Intensification: The Case for Improving Soil Health". The Workshop was attended by 96 stakeholders from 40 countries, representing governments and inter-governmental institutions, the private sector, research organizations, farmers and NGOs.

The Workshop took place against a back-drop of rising international cereal and fuel prices that have prompted increased concerns over:

- The world's ability to maintain a safe balance between food production and human needs, thus ensuring continuing global food security;
- *Fresh evidence of the vast scale at which scarce arable land is degrading;*
- *The long-term sustainability of the technologies on which agricultural intensification is now based;*
- *The rising cost of energy and its impact on the costs of food production;*
- *A growing scarcity of water available for agriculture;*
- *The need to reduce green-house gas emissions, especially from food production systems in order to mitigate climate change processes, and to enable agriculture to adapt to the impacts of climate changes.*

The consensus of the Workshop was that plough-based farming, as now widely practised, has unsustainable elements, whose continued promotion and application endangers global capacities to respond to the above concerns. The Workshop focused on ways through which farmers can attain higher levels of productivity and profitability while improving soil health and the environment. General agreement was that these outcomes will be achieved through the adoption and implementation of Conservation Agriculture (CA) principles and practices.

The delegates agreed that ample evidence now exists of the successes of CA under many diverse agro-ecological conditions to justify a major investment of human and financial resources in catalysing a shift, whenever and wherever conditions permit it, from tillage-based production systems to those based on minimal soil disturbance, organic residue retention, and crop rotations and combinations. This will lead to large and demonstrable savings in machinery and energy use and in carbon emissions, a rise in soil organic matter content and biotic activity, reduced carbon emissions, less erosion, increased crop water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the apparent increased volatility in weather associated with climate change. It will cut production costs, lead to more reliable harvests and reduce risks especially for small landholders.

This Framework presents the joint thinking of the Workshop delegates on actions that would help to empower many more farmers to engage in management methods centred on CA principles, thereby enabling land to be farmed more intensively, productively, profitably and sustainably.

1. The central issue Can plough–based farming be replaced with more sustainable systems in order to safeguard the world's future food supplies?

The world's food supplies will increasingly depend on raising production per unit area of farmed land. The need now, therefore, is for farmers to take up more sustainable, productive and profitable ways of production that do not damage the soil, land and environment. However, the land management systems now applied in many areas of the world, and particularly in the tropical, subtropical and semi-arid regions, are damaging soils and limiting their capacity to generate rising yields on a sustainable basis. Amongst various technological alternatives, the workshop focused its attention principally upon CA based farming systems since they appear to have the potential to be applied on a global scale and to do much to ensure the future adequacy and security of the world's food supplies while improving farmers' livelihoods.

At present, the almost standard, world-wide preliminary to planting a crop requires farmers to either dig or plough their soil, turning it over in order loosen it and to bury weeds and the residues of previous crops, and then to harrow it to create a fine seed-bed. To maintain fertility, "modern" farmers, when they can afford it, rely largely on the application of inorganic fertilizers to replace the soil nutrients taken up by their crops. Most agencies that advise farmers on technology choices – and the firms supplying inputs – recommend that increased production should come from more frequent cultivation, higher levels of fertilizer and pesticide applications and the use of seed of improved varieties.

This type of farming has enabled global food production to expand in line with fast rising demand but there is a growing recognition that they are damaging top-soils and, in many situations, are no longer sustainable.

Moreover, they have not succeeded in ensuring that all people have enough food of adequate quality to eat or that levels of poverty are falling significantly amongst rural populations. Yet, at the international level, there are calls for a "New Green Revolution" in Africa[3], implicitly based largely on the promotion of these technologies. Substantially funded emergency measures to respond to the current food price crisis also focus on boosting output principally through making externally supplied inputs more readily available to farmers.

The problem is that, in many situations the combination of increasingly frequent inversion tillage, a failure to apply nutrients at sufficiently high levels to prevent "mining", and low levels of biomass restitution to the soil results in a progressive degradation of soil structure and fertility. This in turn may lead to increased production costs and reduced profitability of farming. Such degradation is the consequence of both mechanical damage to the soil (compaction and pulverisation) and an associated decline in its organic matter content and biodiversity, especially when crop residues are not retained. The result is a breakdown of soil aggregates and a reduction in the pore spaces within soils that are vital for their functioning as effective media for plant growth. Tillage also reduces numbers of soil fauna, most noticeably a reduction in earthworm numbers with their inherent capacity to aerate the soil and incorporate organic matter to depth.

These tillage-induced processes lead to physical changes in soil structure with subsequent reduction in a soil's capacity to absorb and hold the water and air needed for season-long plant growth, particularly in dry and drought-prone situations. Reduced *in situ* infiltration of rainfall, in turn, causes greater run-off over the land surface, raising the risks of erosion, catchment degradation and more variable stream-flows. Loss of organic matter also lessens the chemico-biological processes, so important in providing the humic gums which contribute to the stability of soil aggregates and release nutrients for uptake by plants.

The reduction in soil organic matter due to frequent tillage is particularly deleterious in tropical and subtropical conditions under which soil carbon is oxidised quickly. The recently published Global Assessment of Land Degradation and Improvement indicates that one fifth of the world's

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[3] Significantly, however, NEPAD's Comprehensive Africa Agriculture Development Programme (CAADP) gives explicit priority to measures leading to sustainable land and water management, including better land husbandry. The Alliance for a Green Revolution in Africa (AGRA) stresses the importance of applying Integrated Soil Fertility Management practices, combining inorganic and organic sources of nutrients but is not explicit about the need for reducing tillage. The recently issued report of the High-Level Task Force on the Global Food Crisis, entitled Comprehensive Framework for Action, includes a Box on Sustainable Food Production Systems: Soil Fertility and Sustainable Agriculture.

cropland - that accounts for only 12% of the earth's land area - is degrading. This reduction in the inherent productive capacity of intensively farmed land is commonly masked by heavier applications of fertilizers, at an ever increasing cost. However, this is only a temporary solution, and, over time, the continued reduction in organic matter levels leads to reduced availability of plant nutrients and increased susceptibility to water stress, resulting in yield reduction that cannot be stopped just by applying more fertiliser inputs. In short, farming as now widely practised, is not sustainable in the long run, from either environmental or economic viewpoints. It is unfortunate that most governments and the international community continue to promote these farming methods throughout much of the intensively farmed areas of the world, contributing to massive, though largely un-noticed, damage to the fragile layer of top-soil on which the future supply of humanity's growing food needs depends.

However, the means of stopping, and with time, reversing these various forms of degradation are already known and farmers are applying them on substantial areas, and improving their livelihoods in the process. The "key" to a sustainable future is to move towards more ecologically friendly farming systems that are more effective in harnessing nature to sustain higher levels of productivity. Critical to this is an increase in the quantities of organic matter on and in the soil, so as to provide the surface-protection, energy and nutrients required by soil-inhabiting flora and fauna that constitute the "life" of a soil, playing a vital role in maintaining its porosity, enhancing its moisture holding capacity and extending the availability of nutrients to crops.

CA and other similar systems for intensive farming that lead to the progressive build-up of soil organic matter have been successfully tested and applied by farmers in many parts of the world over the past 40 years. Though these systems vary in the technologies applied across countries, climates, soils and crop types, their common features are that they enable farmers to create conditions favourable to biotic activity in the soil through:

(a) maintaining, to the extent that local conditions allow, a year-round cover over the soil provided by the current crop, including specially introduced cover crops and intercrops and/or the mulch provided by retained residues from the previous crop;

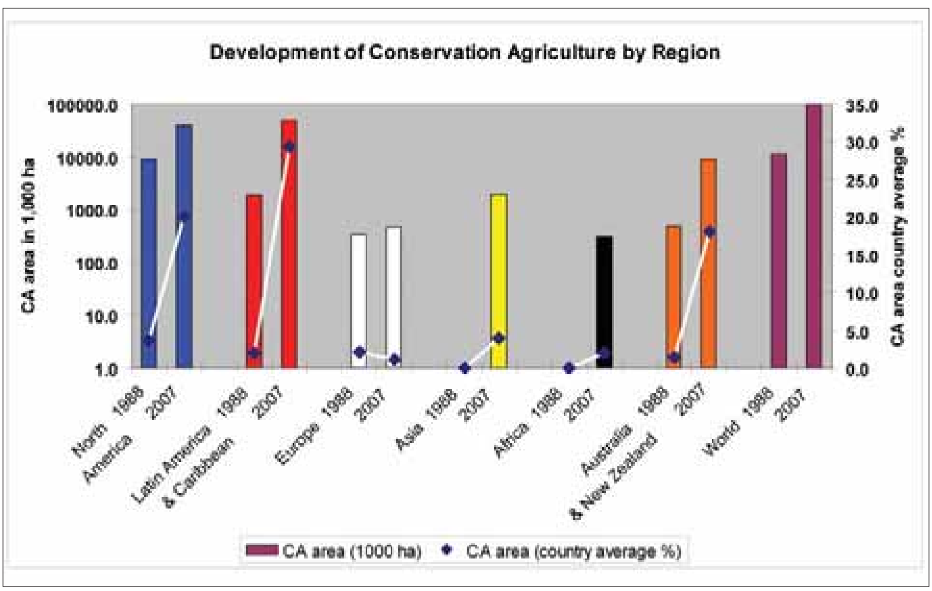
(b) minimising soil disturbance by tillage, eliminating tillage altogether once the soil has been brought to good condition, and

(c) diversifying crop rotations, sequences and combinations, adapted to local socio-economic and environmental conditions, which contribute to maintaining biodiversity above and in the soil, and help avoid build-up of pest populations within the spectrum of soil inhabitants.

Although much of the CA development to date has been associated with rainfed arable crops, farmers can apply the same principles to increase the sustainability of irrigated systems, including those in semi-arid areas. CA systems can also be tailored for orchard and vine crops with the direct sowing of field crops, cover crops and pastures beneath or between rows, giving permanent cover and improved soil aeration and biodiversity[4]. Functional CA systems do not replace but should be integrated with current good land husbandry practices.

Because of the benefits that CA systems generate in terms of yield, sustainability of land use, incomes, timeliness of cropping practices, ease of farming and eco-system services (Box 1), the area under CA systems has been growing exponentially, largely as a result of the initiative of farmers and their organizations (Figure 1). It is estimated that, worldwide, there are now almost 100 million hectares of arable crops which are grown each year without tillage. Except in a few countries, however, these approaches to sustainable farming

FIGURE 1:
Development of Conservation Agriculture over the last 20 years by world region in total area (ha) and as average percentage across the adopting countries of the respective region.



[4] The common constraint, given by farmers, to practising this latter type of inter-cropping is competition for soil water between trees and crops. However, careful selection of deep rooting tree species and shallow rooting annuals resolves this.

have not been "mainstreamed" in agricultural development programmes or backed by suitable policies and institutional support, and the total area under CA is still very small relative to areas farmed using tillage.

The successful spread of CA, however significant the potential benefits may be, requires that a number of constraints – including the widespread perception amongst farmers that inversion tillage is an essential part of crop production processes – have to be overcome (Box 2). The constraints tend to be most severe amongst small-scale farmers who already face many risks to their livelihoods. In some countries attempts to introduce CA have failed, not necessarily because the three CA principles have proven inappropriate but because the process of adaptation and promotion has not been suited to local socio-economic realities or been mainstreamed into farm extension programmes supported by strong cases of local CA successes.

The key issue faced by the Rome workshop and addressed in this Framework for Action, was how to accelerate the participatory adaptation and large-scale uptake, wherever appropriate, and in forms fitted to the diversity of local conditions and constraints, of CA-type systems. And in these ways to safeguard the world's capacity to produce a sustainable supply of food and other farm products for its future population, while at the same time providing farmers with sustainable livelihoods.

It was agreed that this acceleration will require nothing short of a revolution in the way farmers, their advisers, scientists and those who influence farming policies think about, decide and act regarding soil and crop management. The main focus of this Framework is, therefore, on defining the processes needed to induce and support this paradigm shift.

BOX 1 **Sources of Benefits from Conservation Agriculture**

The adoption of CA practices will normally bring direct, though not always immediate, financial rewards to farmers. It will also generate other important economic, social and environmental benefits. To the extent that these are subject to market failures, the creation of incentives, policies and legislation to encourage adoption would be justified

Financial benefits for farmers

- Greater stability in yields;
- Higher ratios of outputs to inputs;
- Reduced demands for labour and much lower costs of farm power, through reduced tillage and weeding; *though not true initially in manually weeded systems.*
- Greater resilience to drought – through better water capture and soil moisture retention;
- Release of labour at key times in the year, permitting diversification into new on-farm and off-farm enterprises.

Benefits to communities and society

- Greater supply of environmental services from landscapes;
- More reliable and cleaner water supplies: lower treatment costs;
- Less flooding – through better water retention and slower run-off: less damage to infrastructure – e.g. roads and bridges.
- Better food and water security.

Environmental benefits

- Conserves soil and water and hence better hydrology and flows in rivers;
- Reduced incidence and intensity of desertification;
- Increased biodiversity both in the soil and the above-ground agricultural environment;
- Lower levels of soil sediments in rivers, dams and irrigation systems;
- Greater carbon sequestration and retention in soils; reduced emissions of greenhouse gases including those of carbon and nitrogen origin;
- Reduced need for deforestation – through land use intensification, and more reliable and higher crop yields;
- Less water pollution from pesticides and applied nutrients;
- Less soil compaction through reduced use of heavy farm machinery.

BOX 2 Constraints to adoption of Conservation Agriculture

- **The mind-set of the plough.** The plough has become the symbol of agriculture and many, including farmers, extension agents, researchers, university professors and politicians have difficulty in accepting that agriculture is possible without tillage.
- **Competition for crop residues.** Most small-holder farmers manage mixed crop/livestock systems and rely on crop residues for animal feed and often fuel. CA systems need to incorporate components that provide for animal feed while at the same time enabling adequate soil surface residue cover. There is room to turn this constraint into an advantage through linking CA and intensive livestock production.
- **Social issues.** Communal grazing rights often apply in rural communities making it difficult for farmers to decide unilaterally that they will keep residues on their fields. Changes in communal and local policies may be required to allow for residue retention. Fire protection may also be necessary.
- **Weed control.** The principal function of tillage is weed control and so, when tillage stops, weed control becomes a major factor. In many cases controlling the weeds present at seeding time has been achieved with herbicides, especially the wide-spectrum “glyphosate”. However, for farmers who do not have access to herbicides or the equipment to apply them, or want to engage in organic farming, manual weed control can be difficult and very time-consuming in the first years of practicing a CA system. After a few years of good weed control and use of cover crops, weed populations decline and become more manageable.
- **Sufficient fertility amendments.** The success of CA depends on adequate residue cover. In very infertile and degraded soils sufficient fertility amendments must be applied to increase production not only of the economic portion of the crop but also of the residues/cover crops.
- **Input market linkages.** Poor linkages may limit farmer access to fertilizer and other inputs for well managed crops.
- **Knowledge intensity.** CA is a knowledge intensive system and farmers, extension agents and researchers need to obtain, share and integrate new knowledge into their practices. Small-holder farmers are often poorly linked to knowledge and information systems, and even extension personnel in many developing countries may have little access to new information.
- **Land tenure.** Farmers that do not have secure access to land may be reticent to invest the time and effort in conserving and improving the land when this may not provide them with longer term benefits.

BOX 2 **Constraints to adoption of Conservation Agriculture**

(continued)

- **Equipment.** Small-scale equipment for seeding crops without tillage is not readily available in many areas. Suitable equipment needs to be introduced, tested and adapted, and local manufacture stimulated where possible.
- **Excess soil water.** CA captures and conserves more water in the soil. As such it is not well adapted to soil types with poor drainage as it may exacerbate problems of waterlogging. However, permanent raised beds which ensure that part of the root system is in aerobic conditions offer a possible solution.
- **Time.** The principles of conservation agriculture need to be adapted to local biophysical conditions and farmer circumstances. This takes time, and massive short-term uptake of CA is difficult – a problem for politicians looking for short-term impact.
- **Policies.** Often the policies and procedures of governments and international institutions tend to favour short-term approaches to stimulating agricultural output and keeping consumer prices low, rather than encouraging sustainable land management and the creation of conditions in which farmers are rewarded with adequate livelihood prospects, including compensation for ecosystem services.

2. The ingredients of successful CA: Lessons from experience

Initial work on "no-till" or "zero-tillage" agriculture began in the USA in the 1950s. Amongst developing countries, Brazil has the longest experience in CA and since 1962 many useful "lessons learned" originate from there and from neighbouring Argentina and Paraguay. Their experiences have contributed to a better understanding of the long-term biophysical and environmental effects of CA application. They have also set important precedents for the engagement of farmers as principal actors in the development and adaptation of new technologies. Farmers in many other countries in Asia and Africa have also gained valuable but more recent experience on how to adapt the principles of CA to their own conditions.

Brazil took the initiative when herbicides (Paraquat/Diquat) and direct-drilling equipment became available in the US, and it became clear that conventional ploughing was leading to a severe environmental and economic crisis for farmers in southern Brazil. Progressive and wealthy farmers led the way, some traveling to the USA to learn about their soil conservation systems and to purchase direct-drilling equipment. Next, "common interest groups" were formed initially amongst large-scale farmers and later with small-scale farmers. CA has emerged mainly as a result of farmer innovation together with problem-solving support from input supply companies, state and federal research and extension organizations, universities, as well as long-term funding commitments from international donors such as the World Bank and GTZ. However the momentum for innovation and adoption has been, and still is, principally with farmers and their organizations.

Apart from enabling their land to be cropped more intensively without risk of degradation, CA attracted Brazilian farmers because it increased crop yields (at least 10-25%), greatly reduced surface runoff and soil erosion, and cut tractor use, resulting in big savings in fuel and production costs (see Box 1). Such benefits explain why today, South American farmers practice zero tillage CA on a continuous basis, year after year, on about 47 million hectares.

The main crops grown under CA include soybean, maize, wheat, sunflower, canola as well as cassava, potato and a number of horticultural and cover crops. CA practices are also being applied to perennial crops and to tree crops. Soil cover is achieved by growing cash crops and cover crops either in association or sequentially. Main cover crops include oats, oilseed-radish, rye, lupins, vetches, mucuna (velvet bean) and pigeon peas, depending on the scale of farms. In some cases, especially amongst small-scale farmers, herbicide use can be reduced by direct-drilling seed into a cover crop that has been flattened using a knife roller. Specialised no-till equipment has been developed in Brazil and the Americas, including tractor-mounted, animal drawn and hand tools (including jab planters). These are being exported to Africa and Asia and being adapted there for local use and manufacture.

For their part, Asian and African countries have begun to take up CA practices only in the last 10-15 years, but have already acquired many useful lessons with respect to adapting the principles of CA to a vast diversity of conditions and constraints. Among the most encouraging experiences has been the CA work developed in dry environments (such as Kazakhstan and Tunisia) with highly innovative adaptations being made to the very demanding low winter temperatures and low and unpredictable rainfall. In DPR Korea, the introduction of CA has made it possible to grow two successive crops (rice, wheat) within the same year, through direct drilling of the second crop into the stubble of the first. The feasibility of growing potatoes under zero tillage has also been demonstrated in Korea.

Innovative participatory approaches are being used in Africa to develop supply-chains for producing CA equipment targeted at small holders. Similarly, participatory learning approaches such as those based on the principles of Farmer Field Schools are being encouraged to strengthen farmers' understanding of the principles underlying CA and how these can be adapted to local situations.

The corresponding programmes recognize the need to adapt systems to the very varied agro-ecosystems of the regions, to the extreme shortage of land faced by many farmers and to the competing demands for crop residues for livestock and fuel – problems that are particularly pronounced amongst small-scale farmers in arid and Mediterranean regions.

While large numbers of small-scale farmers – in Paraguay, China and various African countries – have taken up CA, experience indicates that adoption tends to be at a much slower pace than amongst larger-scale farmers. With food security among their major objectives, many small-scale farmers are hesitant to invest scarce labour, land, seed and fertilizer in cover crops that do not result in something to eat or to sell. They also suffer from restricted access to relevant knowledge as well as to inputs or credit. As a result, there is an increasing recognition of the need to encourage farmers to move towards full adoption of CA at their own pace, testing out promising approaches initially on small areas of their farms and progressively expanding as their confidence in the results develops.

The largest areas under CA nowadays are in the major grain exporting countries (USA, Brazil, Argentina, Canada, Australia) (Table 1). CA is being taken up rapidly in a number of Asian countries (DPR Korea, China, Kazakhstan).

TABLE 1

Conservation Agriculture adoption by country over the last 20 years in ha and in percent of total arable land (source: FAO AQUASTAT 2008)

Conservation Agriculture area in 1,000 ha

	1988-1991	1993-1996	1998-2001	2003-2007
Argentina	500,0	3.950,1	15.000,8	19.719,4
CA area (%)	1,8	13,9	51,5	66,8
Australia	400,0			9.000,0
CA area (%)	0,8			18,1
Bolivia				550,0
CA area (%)				16,9
Brazil	1.350,0	8.847,0	18.744,5	25.501,7
CA area (%)	2,3	13,5	28,2	38,3
Canada	1.951,2	4.591,8	8.823,5	13.480,8
CA area (%)	3,8	8,8	16,9	25,9
Chile				120,0
CA area (%)				5,2
China				100,0
CA area (%)				0,1
Colombia				102,0
CA area (%)				2,8
France	50,0			150,0
CA area (%)	0,3			0,8
Kazakhstan				1.790,6
CA area (%)				8,0
Mexico				22,8
CA area (%)				0,1
New Zealand	75,0			
CA area (%)	2,0			
Paraguay		200,0	1.200,0	2.094,0
CA area (%)		7,4	33,4	48,7
South Africa				300,0
CA area (%)				1,9
Spain				300,0
CA area (%)				1,6
United Kingdom	275,0			
CA area (%)	3,9			
United States of America	6.839,2	17.361,0	21.124,6	25.252,4
CA area (%)	3,7	9,6	11,8	14,3
Uruguay			753,5	1.082,3
CA area (%)			53,4	76,7
Venezuela (Bolivarian Republic of)				300,0
CA area (%)				8,7
World total	11.440,3	34.949,9	65.646,9	**99.866,0**

3. Goals and strategy

The evolving family of CA practices presents farmers and the various institutions supporting them with many productive opportunities to deal with current problems that are likely to become more stressful in the future: food and fuel price increases, labour shortages, water constraints, soil degradation, and adverse climate impacts.

The immediate **goals** of CA include increasing the productivity of land, water, labour and capital to meet human needs, while preserving the integrity of the natural ecosystems on which all life depends. Specifically, CA aims to conserve and enhance the quality of natural and human resources, while achieving greater profitability of agriculture for producers, assured supply and better-quality food for consumers, and greater and sustainable livelihood opportunities to raise standards of living broadly and equitably.

CA practices contribute to the **broader goal** of sustainable agriculture by the synergistic management of soil, water, plant and animal, labour, and soil biotic resources. While the main examples of CA have been developed and demonstrated in the domain of field crops, CA practices are applied also to plantation crops, livestock production, agroforestry, and enrichment of soil biodiversity to capitalize upon inter-specific interactions in supportive environments above- and below-ground.

As a result of the presentations and debates at this workshop, we are convinced of the desirability of enabling many more farmers around the world to take up CA practices, both in their own interest of securing a better livelihood and in the broader public interest of conserving the quality of agricultural lands so that they can continue to be productive. To achieve this goal, we are committed to sharing our collective knowledge and experience in introducing CA approaches to new countries and in supporting the accelerated adaptation and uptake of CA practices in countries in which they have already been introduced.

Agronomic strategies for CA aim at harnessing the abundant and diverse life forms that exist within soils to enhance their long term productivity. They include various combinations of:

- minimal or zero tillage;
- continuous soil cover often including green manure and cover crops;
- crop rotations, sequences and combinations;
- non-inversion weed control, including the use of allelopathy and smother crops;

- crop-livestock integration in farming systems;
- integration of perennial plants in farming systems;
- increase in biomass inputs to soil systems;
- optimization between organic and inorganic nutrient amendments;
- ecosystem-based and integrated management methods to control weeds, pests and diseases;
- erosion control infrastructure where needed;
- methods to increase soil absorption and retention of water (*in situ* "green water");
- enhancement of soil biological diversity and beneficial activity.

Organizational strategies include:
- participatory, farmer-centered research and development;
- greater assumption of responsibilities for agricultural innovation by farmer organizations, including catchment groups, and individual farmers;
- capacity building within such organizations and within specialized research and extension agencies especially to support scaling up;
- engaging the best modern scientific expertise for better understanding of below-ground processes and potentials driven by roots and soil biota;
- creation of incentives and certification of sustainable agriculture practices to recognize societal benefits and encourage uptake of sustainable farming systems; and
- establishment of a network of Communities of Practice (CoPs) bringing together diverse stakeholders around the world to give concerted support for changing mindsets, expanding institutional investments, sharing knowledge and experience, and promoting best practices.

4. Proposed actions

Set out below are summaries of the deliberations of 3 working groups that met during the workshop to identify critical issues, to set goals for what might be done about them, and to propose actions. At this stage, no attempt has been made to set priorities amongst the proposed actions, but these are expected to emerge from the further collective thinking within the proposed CoPs.

4.1 SCIENCE AND TECHNOLOGY DEVELOPMENT

Strategic issues

- CA is characterized by the three central principles of no-tillage, soil cover and crop rotations; but there are many specific technologies that have to be appropriately selected and combined to apply the three principles in practice in ways that are attractive to farmers in very different agro-ecological settings.
- Whatever the technology combinations, good crop, land and livestock management must be constantly assured for the system to function well.
- CA is not a static technology but a dynamic system that will differ depending on biophysical and socio-economic conditions and evolve over time. R&D programmes must respond to this need.
- The contributions of numerous branches of the technical and social sciences, economic disciplines, stakeholders and interest groups must be combined in developing technologies and systems that are adapted to varied conditions and users[5].
- Diverse providers and investors need to be involved in science and technology development for CA, including international agencies, multi-donor programmes, NGOs, government staff, academic institutions, commercial companies and agribusiness, each bringing different expertise but achieving synergy through using common disciplines and indicator sets.

[5] Disciplines include crop science (breeding and seed supply of both cash and cover crops, including legumes), soil science (physical, hydric, chemical and biological), crop management for dryland and irrigated conditions (rotations, beds, fertilizer), climate change (gaseous emissions and carbon), biofuel production, weed and pest control, livestock, engineering (machinery production and development), social-economic sciences (family, gender, labour, time, drudgery, alternate farm enterprises, the economics and benefits of CA uptake), as well as politics (local, regional and national policies and their implementation).

Goals

- Research and development programmes to provide a common framework of knowledge, including a set of indicators for information collection and dissemination, that (i) quantifies and demonstrates the link between CA and soil health that underpins all the other benefits (ii) compares the technical, social, economic and environmental benefits of CA to farmers and society with conventional agricultural practices, (iii) ensures continuing improvements in CA over time and (iv) allows for integration of CA into farming systems.
- Research and development to provide a platform to scale up CA from the plot level to the farm and landscape level, and to mitigate climate change and desertification.

Priority actions

- Quantify the process changes that demonstrate why CA-based systems are better and more sustainable than conventional agriculture systems, including generation of more rigorous information on the benefits to farm family livelihoods and the broader society.
- Evaluate capital losses from soil degradation and the economic gains to be derived from CA-linked rehabilitation.
- Develop crop/soil/livestock/economic system models that integrate the effects of CA systems; extrapolate results to other regions and conditions and indicate areas that require further research and understanding.
- Prepare "Frequently Asked Questions" (FAQs) or "mythbusters" to respond to the most commonly raised questions/misunderstandings about CA.
- Study the processes of innovation and diffusion of CA practices and the dynamics of on-farm and collective decision-making with the objective of understanding if and how uptake can be accelerated.
- Deepen understanding of management options and trade-offs of crop/ livestock CA systems, including the increased productivity of marginal or degraded lands.
- Improve CA machinery to move beyond expensive imported equipment and create local manufacturing capacities and markets to meet growing demand: consider the special needs of small farmers with little cash or credit to buy CA equipment.
- Set up R&D programmes to refine choices of crops and rotations within CA.
- Building on current CGIAR centre initiatives, create a set of CA observation sites worldwide in major agro-ecosystems to provide focal points for strategic long-term research, applied on-farm research, farmer adaptation and impact assessment studies, training and learning nodes.

- To aid building the CA knowledge base, where possible use common indicators and benchmarks in monitoring and evaluating trials in different regions.
- Aim for synergies of inputs/outputs and cross-cutting scenarios by promoting active inter-country and inter–agency networking for data and information sharing.

4.2 UNDERPINNING SCALING-UP OF CONSERVATION AGRICULTURE

Strategic issues

- A single global strategy for up-scaling CA will not work: strategic approaches must be tailored to countries, regions or even local sites, reflecting specific technical, economic and social conditions.
- The needs, technologies and potentials for CA uptake by large- versus small-scale farmers are distinct, and must be tackled in a differential manner. Linking the learning and uptake processes of large and small farmers offers potential payoffs in speeding uptake, but effective and equitable links must be built.
- Upscaling cannot be hastened: the pace of local adaptation and dissemination of CA principles must be compatible with the capabilities of farmers, support services and other stakeholders.
- For small-scale, risk-averse farmers especially, introducing CA will often be stimulated by providing targeted incentives, and fair cost-sharing and risk protection arrangements over several years. These may be perceived as a just compensation for the many eco-services that adoption of CA is likely to generate for the benefit of society at large.
- Wherever possible, simultaneous uptake by farmers of all three CA principles is desirable to achieve greatest impact. But a step-wise approach to the introduction of the principles may at times respond better to farmers' constrained socio-economic situations, scarce resources and perceptions of risk.
- Ensuring the availability of well-prepared advisers and facilitators is key to minimize the potential negative effects of suboptimal performance of CA systems in the early years of their introduction.

Goals

- Location- and client specific knowledge and mechanisms to be available to all categories of target farmers that empower them to understand the CA principles, support them in transition to CA in their own situations, and transmit their experience to other groups.
- Farmers and communities to be empowered to recognize which technical approaches to CA principles are appropriate to their own situations, apply them and transmit their experience and ideas to others.

- Farmers and communities who take up CA to be willing to accept the risks of change and receive full value for the wider benefits to society that they thereby generate.

Priority actions

- Build CA introduction within the context of the overall functioning and dynamics of local farming systems and their changing environment; address economics, crop-livestock interactions, gender and cultural aspects, among others - but do not over-estimate possible rates of change.
- Ensure close partnering from the start among diverse stakeholders in adapting, promoting and supporting CA uptake – e.g. farmers and their organizations, research, extension services, service/input/credit providers, government agencies, NGOs, etc.
- Ensure that farmers assume a leading role in the process, developing as appropriate local, national and regional CA networks/task forces to facilitate capacity building, sharing of knowledge and active mutual learning.
- Develop knowledge management systems at the scales required to provide stakeholders with quality evidence on the performance of CA, its impact, successes and failures, under their diverse conditions (see section 3, below).
- Assess the specific needs of all target categories of potential CA adopters; tailor empowerment and support arrangements to their specific needs.
- Introduce CA principles pragmatically, based on understanding of realities on the ground. Start change using locally-available inputs and based on local knowledge and beliefs whenever possible.
- Demonstrate benefits of simultaneous uptake of all CA principles from the start but maintain an approach to adoption that remains flexible and compatible with farmers' willingness and capacity to implement CA.
- Pay special attention to the start-up phase of CA adaptation; unless skillfully organized and guided, failures are likely.
- Provide small-scale, risk-averse farmers with targeted incentives or cost-sharing to help them overcome a slow start up of CA, and cover the costs and risks of learning and adapting technology to their particular conditions.
- Link CA focus groups together through networks, forums and exchanges to share experiences and technologies, nationally and internationally.
- Include specific encouragements for larger-scale and more advanced CA practitioners to advise and mentor those at earlier stages of adaptation and uptake.

- Ensure adequate attention is given to supply chains for specialist inputs and equipment when they become necessary, as well as ensuring proper access to input and output markets.

4.3 CREATING SUPPORTIVE POLICIES, PUTTING IN PLACE INCENTIVES AND TAPPING RESOURCES

a. Branding

Strategic issue

The basic principles of CA fully support the overall aims of sustainable agriculture. However they are often confused with other related, overlapping or complementary initiatives for changes to agricultural systems.

Goals

- The public, policy makers, agricultural scientists and farmers to be made aware that, without more attention to soil health, returns from further input intensification of agriculture will continue to decline. Uptake of CA principles is accepted as the future pathway towards sustainable and more profitable agriculture.
- CA principles support and facilitate other initiatives for sustainable agriculture and do not compete with other ‘brands’ such as Sustainable Agriculture or Eco-agriculture.

Priority actions

- Communicate that CA principles fit into the larger context of sustainable agriculture.
- Stress basic principles and understanding that there are a wide range of means of applying these principles in specific contexts.
- Engage NGOs as advocacy partners. Link into efforts that are already developing guidelines for sustainable biomass production.
- For the above, use the expanding CA knowledge bases recommended below.
- Enlist professional PR assistance.

b. Positioning

Strategic issue

Investment in CA offers a tremendous opportunity to contribute simultaneously to progress in resolving major world issues related to food security and prices, reaching MDGs, energy saving, the environment and climate change adaptation and mitigation. There are many ongoing or planned initiatives in these fields within which CA must be positioned.

Goal
A CA approach to become integrated into large scale programmes and processes related to food, the environment, climate change, poverty alleviation, national/regional programmes, including. CAADP, AGRA, the operations of Conferences of the Parties on biodiversity, desertification and climate change, initiatives for food security and poverty reduction initiatives (PRSP), and the programmes of producer networks, large investors and International Financing Institutions (IFIs).

Priority actions
- "Sell" CA's win-win potentials for resolving current global issues affecting agriculture and the environment – e.g. slowing climate change through reduced fossil fuel use, reduced gaseous emissions, increased carbon sequestration from residue retention and build-up of soil organic matter; reduction of the impacts on food security of seasonal weather volatility; contributions to watershed repair through reduced runoff, improvements in water quality and reduced siltation; reduction of desertification due to reduced erosion and permanent ground cover; potentials created for biofuels through sustainable use of marginal land.
- Describe potentials for impacts on such issues within large and small-scale farming systems but show how required approaches differ.
- Build awareness of positive opportunities and constraints for CA within existing and transitional policy environments.
- Publicize CA: consider launching a CA Journal, also stress use of new media forms such as cell phones, DVDs and the internet.

c. Advocacy and Capacity

Strategic issue
CA presents a paradigm change that offers the means to introduce new, beneficial systems that can raise the positive image of agriculture and farmers. However means and capacity for advocacy and change are at present inadequate.

Goals
- The advantages of CA to be understood and well known by the general public, political leaders, decision-makers and stakeholders. There is national enthusiasm and implementation capacity to advance paradigm change.
- Farmers to be seen as stewards rather than despoilers of national land and natural resources.

Priority actions

- Increase attention to agriculture sustainability issues in education and knowledge systems (see below).
- Create alliances with environmental groups (e.g., UNEP, WWF).
- Promote concepts of good environmental stewardship which can be well understood by the general public, various stakeholders and policy makers.
- Promote and acknowledge success and contributions of individual farmers and communities.
- Promote CA role in 'green water' management.
- Support and strengthen advocacy and PR by farmers and their networks to raise the positive image of farming.

d. Knowledge

Strategic issues

v Knowledge systems need to give greater prominence to the successes and potentials of CA and its central role in maintaining agricultural sustainability and profits.

- The CA paradigm scarcely features in education and training programmes, most of which continue to teach inversion tillage as central to sound agricultural practice. Funding and curriculum reforms are needed to strengthen knowledge about CA principles, practice and potentials at various levels in education, training, research and development organizations, and as part of farmer training and empowerment.

Goals

- Knowledge and evidence of the potentials and beneficial results of CA to be well known to political leaders, policy makers, donors, the private sector and farmers.
- This knowledge to have secured public support for development of enabling national and local policies, strategies and programmes to promote CA investment.

Priority actions

- Classify and where possible quantify the benefits to society that can result from different approaches to CA adoption. Create public awareness and lobby for policy reforms that will adequately reward adopters or indemnify farmers against risks of change.
- Build and transmit knowledge of CA potentials to all relevant audiences, covering both 'legs' of the issue – needs of small scale and larger farmers.

- Support increased national capacities for knowledge management.
- Within knowledge management systems, assemble experiences covering the costs and benefits of CA, livelihood and social benefits, environmental benefits, also farmer decision/making processes in CA uptake and the dynamics of system change.
- Boost education and training on CA principles and benefits in universities, colleges and schools. Emphasize strategic training/research on appropriate knowledge areas (ecosystem, farm size, socio economics) within the different scientific disciplines, stressing commonality of the CA principles but diversity of the technologies and development approaches through which CA principles are applied. At tertiary level, test/validate the science and products of CA.
- Provide fiscal incentives and use PR and the public media to move education towards better understanding of CA and to overcome entrenched beliefs in the tillage paradigm.
- Assess and respond to knowledge needs along commodity value chains.
- Use large farmers to channel information to smaller farmers. Review and synthesize CA knowledge for wider dissemination.

e. Policy and Incentives

Strategic issues

CA uptake may involve costs and risks to which farmers, especially small-scale farmers in resource poor settings, are averse. Appropriate policies and incentives must be put in place to share costs and risks and recognize the public goods value of environmental benefits generated by widespread CA adoption.

Goal

Specific enabling policies and incentives to be put in place by governments and international institutions seeking to broaden the uptake of CA and by relevant inter-governmental bodies.

Priority actions

Use or develop case studies and the knowledge necessary to justify policy change and incentives for CA uptake, including knowledge on increased agricultural output, C sequestration, reduced N_2O and CO_2 emissions, energy efficiency, cost/benefit improvements, water productivity and watershed functions. Options include to:

- Assist in the evolution of national policies and community or individual incentives geared to CA uptake in general.
- Seek specific government endorsement or recommendation of CA.

- Provide for cost sharing for adaptation, promotion and dissemination of CA technology and to encourage local manufacture of small machinery.
- Encourage international institutions and donors that support CA to adapt their funding instruments to cover the full period necessary for CA to become a permanent element of production systems.
- Develop certification criteria for CA production systems and their products, as a means of increasing value-added for CA farmers.
- Explore incentives for biomass production and carbon retention by small farmers.
- Promote closer working between government and farmers, the private sector, technology generators/disseminators, and NGOs in policy reform, and the design and application of incentives for uptake of CA.
- Create a Competitive Grant Fund for CA research and education

5. Next steps

This initiative has grown out of an increasingly shared and deep understanding among persons from many countries, professions and institutional affiliations of the profoundly biological nature of agricultural systems' performance. Mechanical and chemical interventions can generally produce desirable short-term results and have enabled food production to respond successfully to an unprecedented rise in demand over the past half century. Experience and scientific evaluation, however, are showing that the technologies on which recent growth in farm output are based are less and less sustainable, as soil degradation is becoming an ever greater problem. The rapidly rising cost of petrochemical-based inputs, growing concern for human and soil health, and recognition of the links between intensive farming and climate change processes make it vital for the world's farmers to raise output using methods that do not further compromise the natural resource base for agriculture and diverse ecosystems.

The Workshop participants recognise the value of joint action and wish to contribute to the emergence of greater and sustainable institutional and human capacities to:

- acquire, evaluate, share and disseminate accurate, unbiased and diverse **knowledge** about the principles, practices and impacts of conservation agriculture;
- raise **understanding** in governmental circles, professional organizations and the general public of the benefits, limitations and solutions relating to CA;
- identify, share, enhance and give more ready access to multidisciplinary **expertise** on CA; and
- support diverse **initiatives** for research, extension, advocacy and evaluation of CA that can advance the state of the art and the effective application for CA.

The concept of 'Community of Practice' (CoP) (see Box 3) has emerged within development communities to formalize and strengthen the connections among like-minded persons who work in a variety of circumstances and seek collectively to improve both knowledge and practice. The participants in this consultation propose establishing a number of interconnected CoPs that can further the objectives of CA as discussed above. Modalities remain to be

BOX 3 **Community of Practice (CoP)**

The premises for a CoP:

- The improvement of both theory and practice is greater from a **continuous interaction** between researchers and practitioners than from following the previous concept of a linear process where knowledge is generated and validated separately from practice, being subsequently 'extended' to practitioners;
- There is greater productivity from having **multi-sectoral cooperation** than having a standard 'division of labour' in that different kinds of institutions (public sector, private sector, NGO, academic, grassroots, etc.) have respective comparative advantages to contribute to a collective enterprise and learn from each other; and
- There is great power in bringing together **like-minded individuals** who operate from diverse institutional bases, who are agreed on the general goal even as they contribute different ideas and values about the means for achieving this; excitement and energy as well as information can be generated from heterogeneity that is encompassed within an 'envelope' of broad agreement leading to convergence of community members' perceptions and action.

The value orientations that make a CoP effective include:

- Concomitant valuation of knowledge/theory and of practice, privileging neither one over the other;
- Respect for diversity and for differences of opinion, within the framework of some broader shared objective and concern;
- Appreciation that the world is diverse and changing, and that ongoing, iterative learning is necessary and gratifying.

worked out in detail, with appropriate organizational and financial support, but the outlines of such an emergent capacity can be drawn.

Participants wish to establish and sustain a **multi-stakeholder knowledge management system** that will be suited to the needs of diverse users, and in particular of farmers who can benefit from more appropriate and effective CA practices. Such a system of CoPs, with some overarching identity and common purpose, will engage a variety of agencies, professional organizations, and publics to acquire mindsets and create programmes more supportive of CA.

Implementing the ideas sketched below will be the responsibility of a temporary Facilitating Group, representing all sets of stakeholders and acting on behalf of the participants in this consultation, operating under a charter of purpose that frames the goals and modes of operation which will be circulated to participants by email for concurrence before the Group begins its work. Nominations and volunteers for the Group were solicited from all the participants before the end of the consultation, with the consultation's conveners asked to constitute an optimally sized Group with appropriate representation across sectors, roles, world regions, and disciplines.

Tasks for the Group over the 12 month after it begins work include, but are not limited to:

- Determine the most appropriate and sustainable **organizational arrangements** for the CoP/CoPs, with **administrative support** provided from one or more international organizations that want to facilitate the purpose of the CoP/CoPs.
- Identify possible sources of **financial support**, and enter into discussions with donor agencies to secure the resources needed to operate the envisioned international initiative.

Actions that the CoP/CoPs, when organized, could embark upon could include:

- Establishment of a **multi-functional presence on the internet** that can both provide information on CA and support interactive exchanges among CoP participants. Internet access and email have opened up opportunities for rapid, low-cost and highly interactive communication that we want to utilize. It should support collaborative efforts among individuals, organizations and communities as well as assist in problem-solving and ongoing innovation. Special efforts should be made for this information and these opportunities to be made available to agricultural communities.
- Maintenance of a **register of professionals and practitioners**, from a variety of disciplines and organizations and a variety of statuses who are willing to provide knowledge and support for CA initiatives at international, national, regional or local levels.
- Development of a **network of CoPs** that provide opportunities for greater contributions -- and outputs -- from participants in the overall CA-CoP. Possible focuses of specific CoPs would be:
  - o *Knowledge for CA* – research agenda and priorities available to all persons interested; documentation on CA and evaluation of CA experience; exchange of research outputs, etc.
  - o *Advocacy for CA* – public and professional communication; policy dialogue with decision-makers, etc.
  - o *CA Application* – field support of CA initiatives, such as training modules; cumulative experience on participatory approaches, etc.
  - o *Education for CA* – curriculum improvement in primary and secondary schools; enrichment of university and professional education.

Support for these CoPs might be worked out with several different institutions which are becoming higher-level stakeholders in CA such as GFAR, UNEP, international farmer organizations, and UNESCO, universities and NGOs. FAO is the international organization with the broadest interest and stake in CA and has indicated its willingness to provide the administrative support base for the overall CA-CoP.

- A first activity for the Facilitating Group would be to form task forces from among the workshop participants to draft within the next four months a short **policy paper on CA** and an **analytical paper on the costs and benefits of CA.** These papers could be used in discussions with donor agencies, international organizations, professional organizations, private sector and others.

APPENDICES

Appendix 1: Underpinning Conservation Agriculture's benefits: The roots of soil health and function

Appendix 2: Workshop technical background and agenda

Appendix 3: List of participants

APPENDIX 1

UNDERPINNING CONSERVATION AGRICULTURE'S BENEFITS: THE ROOTS OF SOIL HEALTH AND FUNCTION

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UNDERPINNING CONSERVATION AGRICULTURE'S BENEFITS: THE ROOTS OF SOIL HEALTH AND FUNCTION

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"Despite the artistic pretensions, sophistication and many accomplishments of mankind, we owe our existence to a six-inch layer of topsoil and the fact that it rains".
?Confucius

"Without regular and dependable supplies of food, other agricultural products and water, our whole economic structure will collapse, and no amount of accounting, book-keeping, reckoning, buying or selling will sustain it".
Cormack & Whitelaw, 1957

"Some are predicting that water will replace oil as the resource of greatest concern to the global community – there are alternative fuels, but there are no alternatives to water".

Craig Cox (SWCS) in testimony to the US Senate 17.1.07, Quoted in JSWC (USA) Mar/Apl.2007, p.23a

ABSTRACT

This paper considers features underlying conservation-effective agricultural systems' impacts, because they can explain present successes, suggest guidelines for future initiatives, and indicate criteria for judging their effectiveness. Once farmers have made the transition in awareness, thinking and practice of Conservation Agriculture (CA), positive benefits which attract farmers include savings in time, labour, energy and expenditure, with increased productivity and profit margins, greater stability of production, opportunities for diversification. These are accompanied by agro-ecologic improvements to the physical catchments in which such farms are aggregated, and additional socioeconomic and environmental benefits to the wider community that surrounds them. CA protects and enhances the roots of sustainability whereas conventional tillage agriculture adversely affects soil quality and productivity. CA can offer significant advantages to producers in all agricultural environments including in suboptimal and marginal ecologies. The paper highlights the need to think unconventionally and not to be constrained by the dogma underpinning conventional tillage agriculture. To maximize the opportunity and benefits offered by CA, key areas of further investigations by the scientific and development community are elaborated.

1. Introduction

In many landscapes, we expect three-dimensional catchments which are clothed in soil to yield sufficient vegetation of various types, including crops, and volumes of clean water regularly on an annual basis. It is becoming widely acknowledged that Conservation Agriculture ('CA') systems, when fully expressed, can improve catchments' (often damaged or degraded) capacities to provide these essential biological and ecosystem service products on a sustainable basis. CA simulates formerly-sustainable systems but at higher levels of productivity.

Optimal CA systems are based on at least three practices: no disturbance of the soil; permanent cover of the soil with organic matter provided by mulch and cover-crops; and diversified crop rotations, which preferably include N-fixing legumes in the sequence.

In many areas, to date, satisfying the needs of expanding human populations for water has resulted in increasing rates of draw-down of subsurface groundwater from wells and boreholes, though without other actions to ensure equal rates of replenishment by infiltrated rainfall water. The consequences are all too often a need to deepen the boreholes, and an increased incidence of streams ceasing to flow ever earlier after the onset of the dry season.

Increased demands for plant products including food have been addressed through both intensification of inputs per unit area - particularly of agrochemicals and energy - more fertilizer and pesticides, and expansion of agriculture onto 'virgin' land. In many situations, the resulting increased frequency of physical tillage, more fertilizers and pesticides, and/or expansion onto more 'fragile' types of land have resulted in dynamic re-adjustments of the original ecosystems to altered, less-productive states and, as evidenced - particularly in the tropics and subtropics, but also in temperate regions - by increased soil erosion and surface runoff, and the degradation of soil and water quality and of biodiversity. Soil erosion signifies loss of land quality, of soil porosity and of soil depth, while surface runoff signifies wastage of volumes of potentially-usable water. Neither of these wastages, nor other environmental degradation, are acceptable features of an agriculture which attempts to be productive, efficient and sustainable.

Human populations and their associated demands from the land - to yield plant products and water - continue to rise even as productive potentials of much land continue to fall (or can only be maintained with rising costs of production per unit of output) due to past and ongoing damage to the environment.

1.1 CHALLENGE

The challenge is to reverse the observable trend of what is commonly accepted as 'conventional agriculture' - towards declining sustainability of land's productivity accompanied by increasing costs to farmers, to the environment and to society at large. As additional challenge this reversal in trend has to be combined with an increase in production.

2. Components of soil productivity

Soil plays a central role in agricultural production. It determines the production but also the efficiency of many other production factors and inputs. The productivity of a soil, evidenced by yields of plants and input factor productivities, is derived from four components which interact dynamically in space and over time:

1. **Physical:** its 'architecture', made up of the arrangement of spaces and solid particles and organic materials, including the forces holding the elements together, and a soil's depth, defined in three dimensions; the special arrangement of the elements is as important as their quantitative distribution.
2. **Hydrological:** its capacity to absorb, transmit and retain water received at the surface; the supply of soil water to plants is determined by the range of pore-sizes which determine the water's availability to them. In considering 'soil fertility' rather than 'soil productivity' this feature generally becomes obscured (even though implied) beneath acknowledgement of the physical and biologic components. In CA, 'soil productivity' is the preferred term, because of this stress on soil moisture availability.
3. **Chemical:** dissolved substances which serve as plant nutrients; organic (= C-based) chemical complexes as by-products of organisms' metabolic activities which, with active clays, contribute much to soils' capacities of cation-exchange and of slow nutrient release (broadly equivalent to the importance of a soil's pore-size distribution in 'slow release' of water to roots).
4. **Biologic:** soil-inhabiting organisms - bacteria, fungi, plants, animals, and their non-living residues. The non-living fractions provide energy and nutrients for the activities of the living fractions.

All four components interact under the influences of climate, gravity, available species, and the stability of care and management. As long as undisturbed, the plant/soil ecosystem tends towards a condition of dynamic equilibrium. But, as expression of an ecological principle, under the overriding influences of weather and gravity, changes to one component of soil productivity provoke re-adjustments between all four of them, which may prove beneficial or detrimental in terms of plant production and/or water provision. It is to such disturbance that the detrimental effects of tillage agriculture can be related.

3. Some adverse effects of 'conventional' tillage agriculture

From the description of the elements for soil productivity it becomes obvious that the common practice of tilling the soil does not favour particularly the physical and biologic characteristics of a soil. The nature of 'conventional' agriculture, based on tillage, fails to provide together the three integrated bases of conservation-effective agriculture: (a) no soil disturbance; (b) permanent cover to the soil; (c) rotations of diverse crops, including legumes.

Tillage destroys soil organic matter through two interrelated processes. Organic matter at depth in the soil is slower to decompose as soil temperature and moisture levels vary more slowly at depth and oxygen partial pressure can be lower also. Ploughing brings this OM to the surface and decomposition is speeded up.

The second process is that, when there is no physical disturbance, soil macro-aggregates "occlude" particulate undecomposed residues. The break up of the macro-aggregates exposes this occluded particulate OM (or light fraction) to decomposition. This process has been well described by Six *et al.* (2000) and shown to be true for Ferrasols by Denef et al. (2007) and Zotarelli *et al.* (2007).

- Tillage agriculture generally aims to remove or bury all cover except that provided by the crop itself.
- Under increasing demands and lessening of available land space, conventional tillage agriculture tends towards favouring lesser crop diversity, even to monocropping, as well as to limiting or eliminating regular periods in rotation for soil restoration by the widely-penetrating root systems of appropriate species – such as perennial grasses – which, to an extent, can simulate the effects of former long-rotation 'bush fallows' including shrubs and trees.
- Tillage interferes with the habitat of soil life and disrupts the physical structure of this habitat, replacing the structuring effects of soil life with mechanical restructuring of soil aggregates. This leads to a disruption of continuous pore systems, less structural stability and a clear separation of the tilled topsoil from the not tilled subsoil.

Thus, tillage agriculture results in significant disruptions to the functioning of the living soil/plant system and the interactions between the four components of soil productivity.

3.1 PRIMARY EFFECTS

Primary effect can be seen as:

- Physical disruption of, and degradation of, existing soil pores – stirring, compacting, pulverising, losing organic 'glues' between particles;
- Net loss of organic matter by its accelerated oxidation of carbon compounds and emission of CO2 to the atmosphere, following tillage operations (Figures 1-4). If soil is basically purely inorganic because its soil organic matter reserves have been severely depleted, then applied P fertilizer is usually immobilized almost immediately. The higher the amount of P that can be retained in organic (C-linked) form in residues on the soil surface to act as slow-release fertilizer, the lower is the necessity for high P inputs, and P-fertilizer efficiency improves.

FIGURE 1

Cumulative carbon dioxide loss from soil subjected to different depths and severities of tillage, according to accelerated rates of oxidation of soil organic matter, and possibly to release of CO_2 trapped in soil pores.

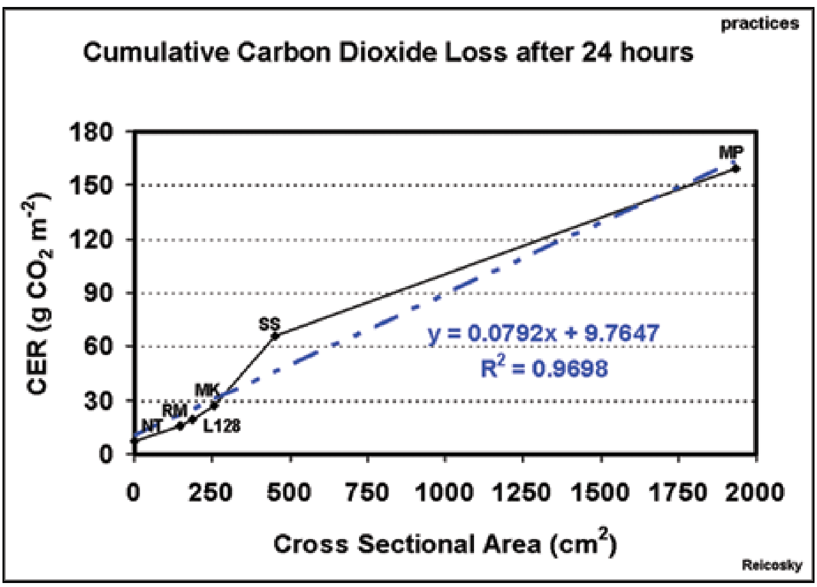
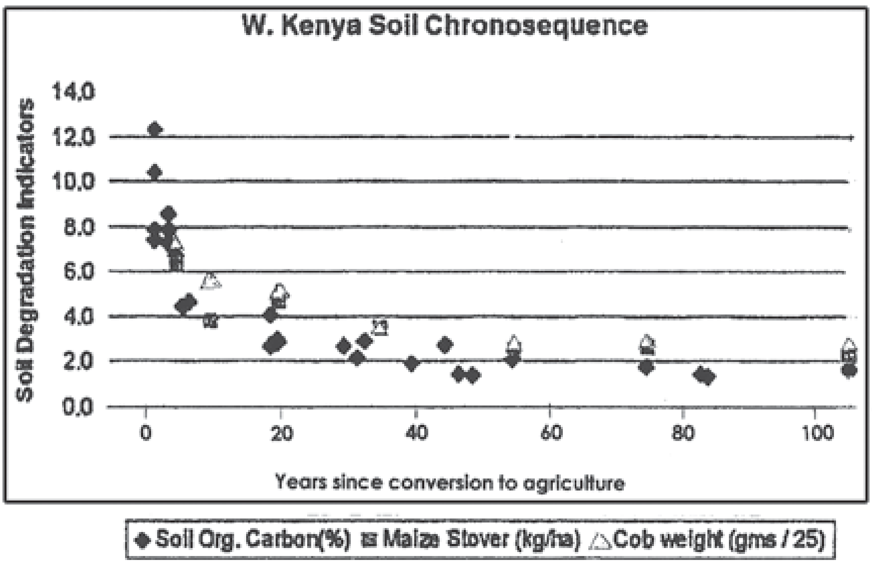


FIGURE 2

Soil organic carbon, yields of maize stover, maize-cob weights decline rapidly during initial years after bringing the soil into tillage agriculture in western Kenya, then continue to decline at slower rates for as much as 100 years.

(From Marenya & Barrett: diagram reversed laterally)



Decline in percent soil organic carbon, weights of maize stover, and maize-cob weights over time since the land's conversion to agriculture
(7 villages in Vihiga and South Nandi Districts in western Kenya).

(After Marenya P.P., Barrett C.B., 2007: 'State-conditional fertilizer yield response on western Kenyan farms'. July 2007, revised draft.
"© 2007 by Paswell P. Marenya and Christopher B. Barrett. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies."

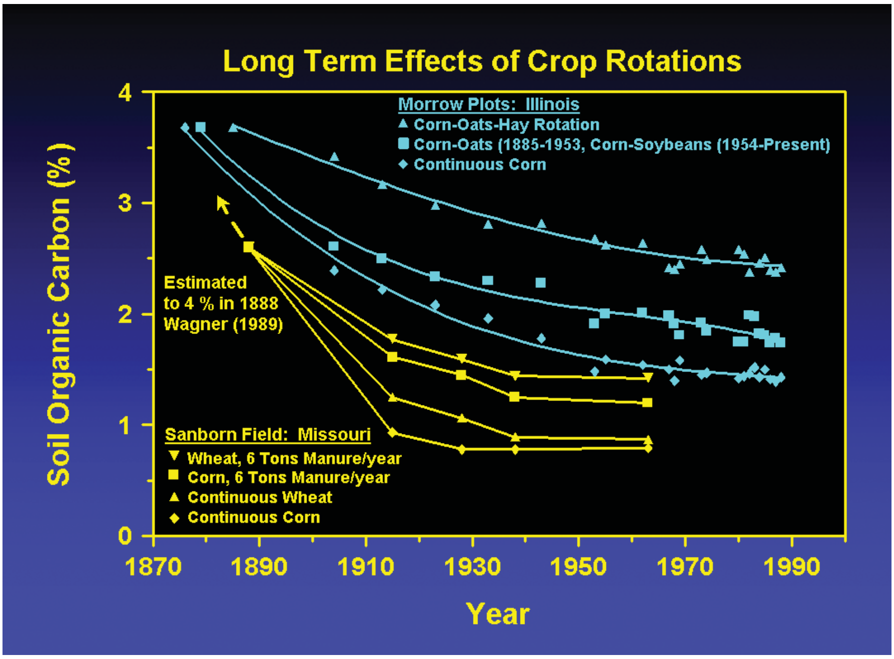
3.2 SECONDARY EFFECTS

As a source of plant nutrients, organic–matter additions (manures, composts) are commonly substituted by manufactured fertilizers, because the latter are less bulky and easier to transport and spread.

Where tillage agriculture then continues, the remaining soil organic matter is further depleted by oxidation, until so little remains (only that most resistant to transformation) that the soil's buffering capacity is exhausted and plants then become more or less wholly dependent on applied nutrients alone.

FIGURE 3

Comparable example of decline in soil organic carbon, from the U.S. Midwest. Even under rotations, and with manure applied, soil organic matter levels still show long-term decline under tillage agriculture, again falling rapidly at first, more slowly in later decades.



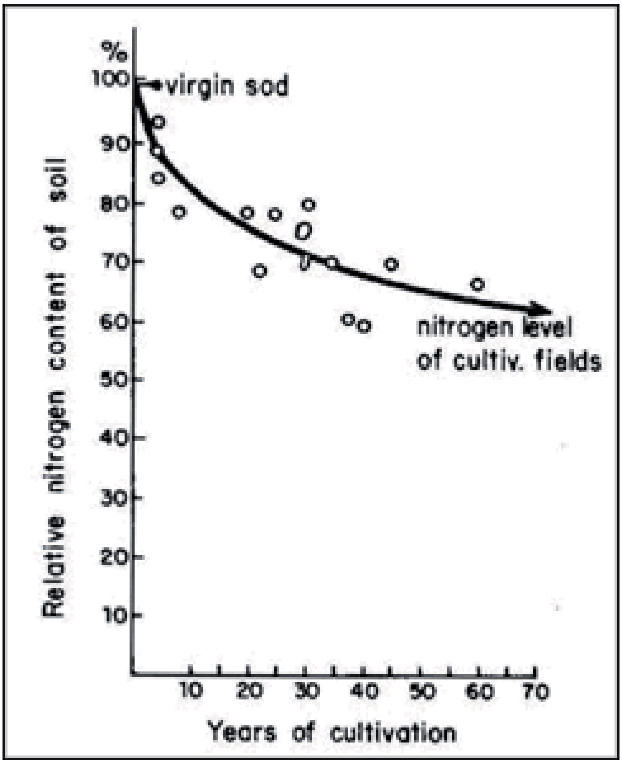
The trend of loss is seen to be rapid initially, followed by slower long-term decline, the shape of the curve being characterized by a Decomposition Constant. This feature was discussed by Nye and Greenland in 'The Soil under Shifting Cultivation' (C.A.B., 1960, p.51+). The diagram below shows a comparable trend over about 100 years 1880-1990 at two locations in the US Midwest between about 1880 and 1990.

3.3 THE 'ELEPHANT IN THE BACK ROOM'

Other investigations suggest that, after s.o.m. has become depleted to very low levels the result has been lower efficiency and eventually minimal effectiveness of mineral fertilizers to contribute to soil fertility and eventually to further enhance yields. This end result has been observed by small farmers: after they could no longer obtain fertilizers (for whatever reason) the subsequent crop yields had become so poor that they have reported: "*The crops have become 'addicted' to fertilizers*"; "(After we stopped using fertilizers), we

FIGURE 4

Comparable decline, in soil nitrogen level relative to that in virgin land (N-levels closely related to organic matter levels)



suddenly realized that something bad had happened to our soil"[6]; *"[It] slowly kills the soil"*[7]. Comparable comments by farmers have also been noted in parts of China[8]. A similar problem occurs if blanket applications of only one fertilizer are applied because, if applied in ever-increasing quantities of e.g. N, eventually other nutrients become limiting and the soil can become effectively sterilized.[9]

"*Using data from maize plots* [some known to have been cultivated for more than 100 years] *operated by small farmers in western Kenya, we find a von Liebig-type relationship between soil organic matter, a broad proxy for soil fertility status, and maize yield response to nitrogen application. On a third*

6 Shaxson, pers comms. (Malawi)
7 Tamang, D, 1993, (Nepal) quoted in FAO Soils Bulletin 75, 1999, p.47.
8 Douglas, pers. comm.(1451).
9 Twyford, pers. comm.(1644)

of the plots, degraded soils limit the marginal productivity of fertilizer such that it becomes unprofitable at prevailing prices. Since poorer farmers most commonly cultivate SOM-deficient soils, stand-alone fertilizer interventions might therefore be less pro-poor than is widely assumed".[10]

If these interpretations reflect the reality, and the situation is widespread across the lands occupied by resource-poor small farmers in the tropics and sub-tropics, it poses a serious challenge to the assumption that inorganic fertilizers plus improved seeds are all that are needed (with adequate rainfall, and/or irrigation) in tillage-agriculture to reverse the observed declines in soil productivity over the years.

Until this problem is resolved, the long-term decline of soil organic matter, illustrated above (Figure 4), is like 'an elephant in the back room', capable of causing and repeating serious problems.

3.4 CONSEQUENCES

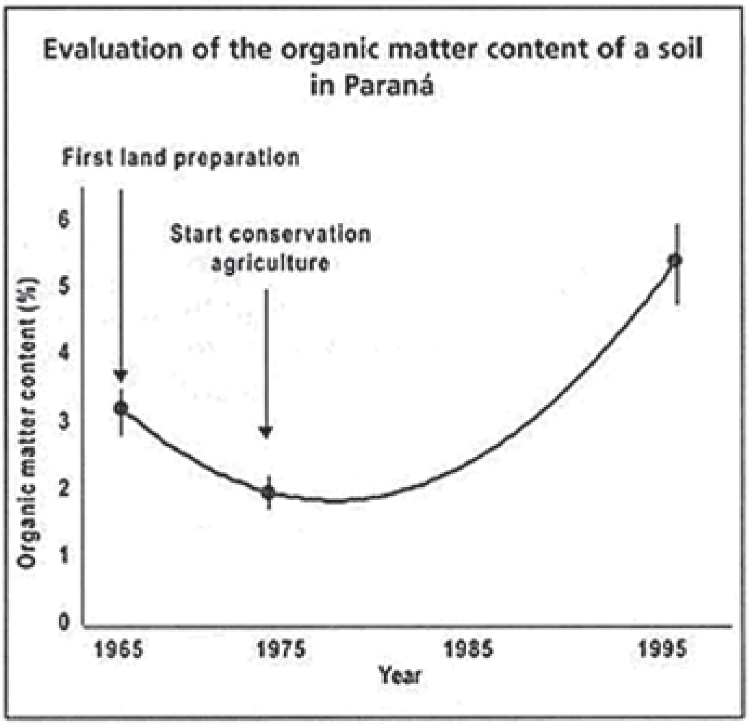
The loss of soil organic matter caused by repeated soil tillage has a number of consequences:

- Raised risks of losses of water as runoff; of soil as 'sediment'; of applied inputs – energy, seeds, fertilizers, pesticides;
- Diminished capacities for capture and slow release of both plant nutrients and water;
- Diminished quality of the soil as a rooting environment;
- Diminishing yields, at level costs, year by year; conversely, level yields maintained at rising costs;
- Diminished activity and diversity of soil organisms;
- Lowered resilience of the soil/plant system to adverse conditions;
- Reduced output/input ratios, indicating falling efficiencies of use of inputs;
- Diminished sustainability of farming enterprises.

CA systems (based on the combination of no-till + permanent organic soil-cover + crop- rotations, which induce net increase in soil organic matter, and in conjunction with provision of sufficient plant nutrients) offer an entirely-appropriate type of solution, potentially able to slow and reverse these damages, and to minimize/avoid their repetition on newly-opened lands.

[10] Marenya P.P., Barrett C.B., July 2007. 'State-conditional fertilizer yield response on western Kenyan farms'. Revised draft, July 2007. Permitted quotation from authors' abstract.

FIGURE 5
Reversal of s.o.m. decline by adoption of CA in Paraná, Brazil.



Source: Bot A., Benites J., 2005:'The Importance of Soil Organic Matter'. FAO Soils Bulletin 80, p.20.

4. Key features of optimum conservation agriculture

Conservation Agriculture reaches its full potentials for sustainable yields of vegetation and water when three features are functioning together:

1. No physical disturbance of the soil
2. Permanent organic cover to the soil
3. Rotation of crops

4.1 NO PHYSICAL DISTURBANCE OF THE SOIL

No disturbance of the soil - once it has been brought into good condition for rooting and for water-entry and -retention - is achieved by direct seeding through the mulch cover without tillage. This feature:

- Enables the living parts of the varied members of the soil/plant system to optimize the arrangement, over time, of the four components of soil productivity (as above) to mutual benefit. It avoids disruptive disturbance of the ensuing self-layering of activity and characteristics from the surface downwards into the profile.
- Preserves the integrity of large pores into the soil made by meso-organisms such as worms, termites etc. and by roots now decayed, along which both water and gases can move fairly rapidly to depth, including balanced exchange of respiration gases between the atmosphere and the zone of rooting .
- By avoiding break-up of larger soil aggregates, prevents exposure of their internal micro-aggregates within which occluded small fragments organic matter are sheltered.
- Permits time for biological transformations of organic matter to build up more soil aggregates which have degrees of resistance to slaking and/or mechanical breakdown by compaction.

In a sense, the soil architecture that develops over time under no till can be equated to the architecture of a building (Figure 6). The functional usefulness of the building depends on the nature and organization of the space within the building.

FIGURE 6

Controlled demolition of twin apartment-blocks. The interesting things happen in the spaces of soil architecture, as in a building. If the spaces are lost, the usefulness is lost, even though the physical parts remain.

4.2 PERMANENT ORGANIC COVER TO THE SOIL

Permanent organic (= carbon-rich) cover to the soil is derived from retained plant residues from crops and cover-crops which have been retained *in situ*, sometimes augmented with manures, composts etc. from elsewhere. This feature:

- Protects the soil surface from:
  - o high-energy rainfall impact, thereby avoiding the associated crusting and compaction of the surface that occurs on bare soils;
  - o extremes of daily temperature fluctuations in uppermost soil layers, which otherwise could be inimical to plant functions in bare soils;
- Provides a regularly replenished organic substrate for the metabolic processes of the soil biota, whose transformative actions on dead organic matter lead to the enhancement of soil aggregation and of a wide range of pore-size distribution within the resulting soil porosity. For root function and water movement the spaces within the pore matrix are as significant as the solids that surround them.

The transformative processes also result in enhancement of the soil's cation exchange capacity (CEC), providing retention and slow-release of plant nutrients, whether derived from organic matter and/or applied 'from the bag'.

4.3 ROTATION OF CROPS

This involves rotation in sequence of several species of crops, including legumes as symbiotic (plant x Rhizobia) sources of plant-fixed atmospheric N, and other usable green manure cover crops, for maintaining soil cover at all times, as well as provision of labile organic residues both at and below the surface. It is important that the nutrient balances in the soil are maintained from one cycle of a rotation to the next. C-accumulation seems only to occur when there is a legume in the system which fixes more N than is removed in the crop products or otherwise lost from the system[11].

This feature results in:

- The placement of organic root-residues at a range of different <u>depths</u> in the soil profile according to each crop's characteristics;
- The provision of various <u>qualities</u> of residues in the soil, from the most labile and readily-transformed to the more-lignified types resistant to decomposition, depending on the plant types. The more-labile/less-lignified forms contribute less to cation-exchange capacity than more-lignified root materials. A wide range of types provided by the different crops increases the range of buffering capacities of the soil with regard to soil pH and nutrient imbalances with respect to plant requirements.

Mixed sequences of crops, plus the presence of permanent soil cover, tend to inhibit the build-up of specific weed species which would thrive under less-varied or monocrop conditions.

The greater the range of plants grown, in mixtures or in sequence, the more varied will be the biodiversity of associations of organisms above-ground and inhabiting the rooting-depth, and the greater the competition which can suppress those which may be detrimental to root function and thus be considered weeds/pests. A crop rotation will further help interrupting the infection chain for diseases and might have other pest-repellent and -suppressing characteristics. For the alterations in copping systems to be worthwhile to farmers, there need to be local uses and/or markets for outputs generated by improved crop sequences.

4.4 SIMULATION OF FOREST-FLOOR CONDITIONS

In CA systems with the above attributes there are many similarities with resilient 'forest-floor' conditions:

- Organic materials are added both as leaf-and-stem residues from above the surface and as root-residues beneath the surface where the soil biota are active and carbon is accumulated in the soil.

[11] Boddey R., pers. comm.

- Carbon, plant nutrients and water are recycled.
- Rainwater enters the soil complex readily, since rates of infiltration – (maintained by surface protection and varied soil porosity) usually far exceed the rates of rainfall income.

The ongoing relative stability of such conditions depends more on the dynamic biological characteristics of the soil/plant ecosystem than on its static physical attributes.

4.5 SOIL ORGANIC MATTER

Soil organic matter is neither just a provider of plant nutrients in low concentrations nor just an absorber of water, as is sometimes supposed. The combined living and non-living fractions together form a key part of the dynamics of soil formation, resilience and self-sustainability of CA systems.

In the functioning of soil as a rooting environment, the integrated effects of the physical, chemical and hydrological components of soil productivity are effectively 'activated' by the fourth, the biological component.

The varied component species of the living fraction of soil organic matter may inhabit the above-ground mulch and/or the soil below.

They variously provide metabolic functions, acting on the non-living organic materials, which include:

- Retaining potential plant-nutrient ions within their own cells, with liberation on their death, acting as one form of slow-release mechanism; mycorrhizae and rhizobia, as well as free-living N-fixing bacteria, make nutrients available to plants in symbiotic arrangements.
- Breaking down and transforming the complex molecules of varied dead organic matter into different substances, both labile and resistant, according to the composition of the substrate;
- Leaving behind transformed materials with differing degrees of resistance to, and thus of speed of, subsequent breakdown by biotic process of other soil organisms. Over the long term, this leaves some residues less changed than others, providing long-lasting and slowly-released remnant reserves of the nutrient and carbonaceous materials of which they were composed.
- Producing organic acids which, by leaching, contribute to soil formation from the surface downwards by acting to break down mineral particles as part of the soil 'weathering' process. Organic acids also help with transporting lime into the soil profile and mobilizing nutrients like phosphates.
- Providing organic molecules as transformation products which contribute markedly to soil's CEC; this also augments the soil's buffering capacity with respect to pH/acidity changes and to excesses or deficiencies of nutrient ions available to plants.

- Providing humic gums which, together with fungal hyphae and clay bonds, make for different sizes of rough-surfaced aggregates of individual soil particles which, within and between them in continuous channels, provides the permeability of the soil in a broad distribution of pore-sizes.
- Burrowing activities of meso-organisms such as worms, and of roots (leaving tubes after they have died and been decomposed), also contribute to the macro-porosity of the soil, with similar effects.

The soils which are most vulnerable to tillage-stimulated rapid loss of soil organic matter are those of coarse texture and where the clay fraction is dominated by low-activity clays. Such soils (e.g., ferralsols) are widely distributed in the tropics and sub-topics, and total over 750 million ha. in these regions.

4.6 THE ROOTS OF SUSTAINABILITY

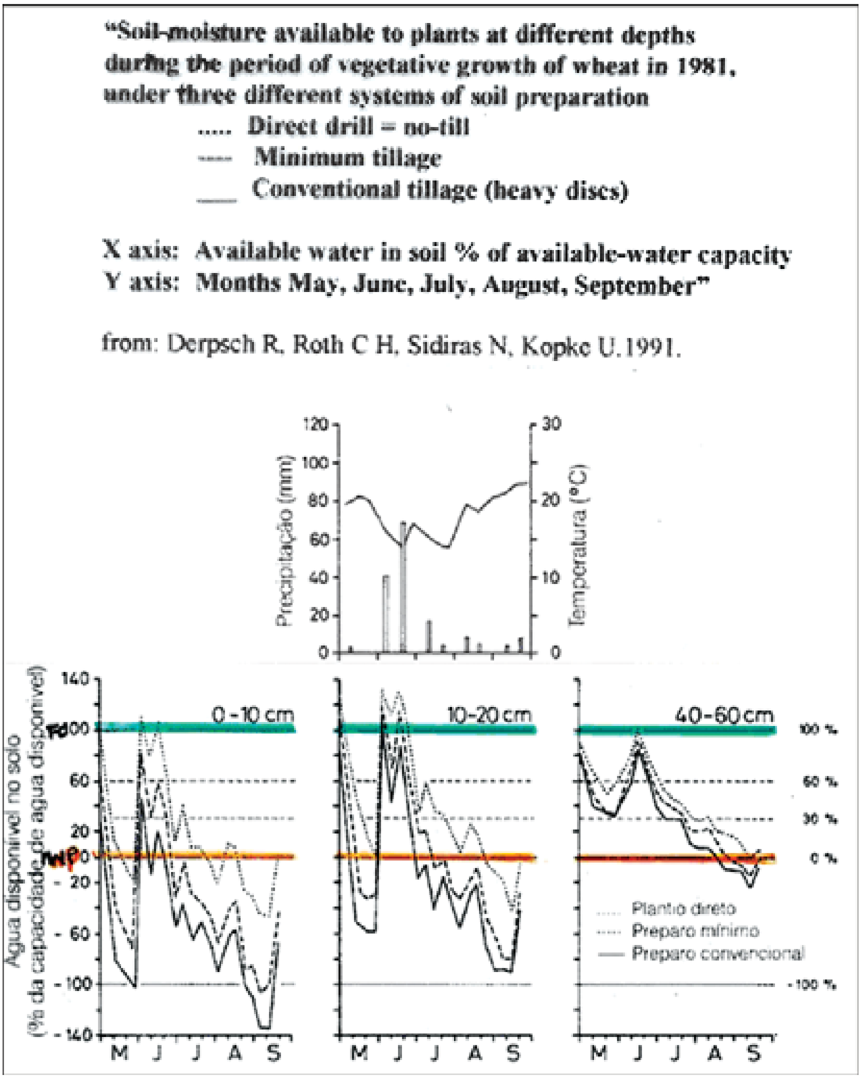
Sustainability of land's capacities to continue yielding both plant products and water year after year depends primarily on maintaining the soil in fit condition for active life processes of the whole soil/plant system. This relates to the ongoing generation and re-generation of the porous soil architecture – the soil's 'self-recuperation capacity' – with respect to repair of damaged soil and to its physical resilience in the face of adverse shocks of weather and/or of poor management.

It is clear that maintaining the vitality of the soil, notably of the number, diversity and activity of the living components of its organic matter, is a key factor in sustaining the land's capacity to go on yielding vegetation and water through maintenance of soil porosity.

The advantage of CA over TA in terms of the duration of plant-available soil moisture is clearly illustrated by the graph in Figure 7, which shows the situation with respect to soil moisture conditions throughout growing-season under three experimental treatments: 'Direct drill' (= no-till conservation agriculture); 'Minimum tillage' (= non-inversion tillage with tines); and 'Conventional tillage' with heavy discs.

Between the first ('Direct drill') and the third ('Conventional') treatments there is a major difference in the duration of plant-available moisture (between Field Capacity and Wilting Point) in the upper 20cm of the soil between May and September of the study-period. The effects of dry weather would have taken effect on the crop much earlier in the plots damaged by conventional tillage than under those maintained under CA management. Stated another way, the crops under the CA system would have continued towards maturity for longer than those in soil with conventional tillage. In addition, the period

FIGURE 7
Soil management and plant-available soil water



Source: Derpsch, Roth, Sidiras, Kopke, 1991. 'Controle da erosão no Paraná, Brasil: sistemas de cobertura do solo, plantio direto e preparo conservacionista do solo'. GTZ, Eschborn. p.76.

in which available nutrients can be taken up by plants is also extended, increasing the efficiency of their use.

The greater the volume and longer duration of soil moisture's availability to plants (between the soil's Field Capacity and Wilting Point) under CA treatment has significant positive indications for farming stability and profitability. The range of pore sizes which achieve this also implies the presence of larger pores which contribute to through-flow of incident rainwater down to the groundwater.

The following two photos (Figures 8a, 8b) indicate the above effects on an experimental field near Foggia, Italy.

FIGURE 8A

This shows the differing appearance of wheat from part under mulch-based zero-tillage for 3 years (in the top-left quadrant beyond the further figure) vs. (in the top-right quadrant) the same variety and fertilizer-treatment but produced with conventional tillage and non-retention of residues from the previous crop. [Photo: TFShaxson]

FIGURE 8B

Representative ears of wheat from the above two quadrants (taken on same day as upper photo). Greater availability of moisture in the root-zone of that under CA management enabled the plant on the left to continue photosynthesising for some time after that on the right, which had run out of available water and stopped. Subsequently, after harvest, 14% more wheat yield/ha. was recorded from the CA wheat than from the TA wheat. [Photo: Des McGarry]

Infiltration rates under well-managed CA are much higher over very extended periods than in TA due to better soil porosity. In Brazil, a six-fold difference was measured between infiltration rates under CA (120 mm per hour) and TA (20 mm ph hour). CA thus provides a means to maximize effective rainfall and recharge of groundwater as well as reduce risks of floods, due to improved water infiltration. Due to improved growing-season moisture regime and soil storage of water and nutrients, crops under CA are healthier, requiring less fertilizer and pesticides to feed and protect the crop, thus leading to a lowering of contamination of soil, water, food and feed. In addition, in soils of good porosity anoxic zones hardly have time to form in the root zone, thus avoiding problems of the reduction of nitrate to nitrite ions in the soil solution.

Such types of information from soils in good condition under CA provide a range of 'yardsticks' against which to compare the benefits of CA and the health of the soil, as against the damages caused by 'conventional' tillage agriculture, as discussed below.

5. Impacts of conservation-effective agriculture

CA's impacts can benefit both people and the wider landscapes that surround them. These benefits attract the interest of others, thus contributing to CA's autonomous spread.

5.1 SOME REALISABLE IMPACTS AT FARM LEVEL[12]

- ✓Labour, time and farm power are saved through reduced cultivation and weeding requirements.
- ✓Lower costs because both operations and external inputs are reduced.
- ✓Mechanical equipment has a longer life-span, lower repair costs, and consumes less fuel.
- ✓Better movement in the field; less drudgery of repetitive work.
- ✓More-stable yields, particularly in dry years because more nutrients and moisture are available to the crops.
- ✓Labour savings provide opportunities for diversification of enterprises and into other activities.
- ✓Yields are increased even as inputs decrease, to a changed equilibrium state, including lowered demand for fertilizers, pesticides, and energy.
- ✓Increased profits, in some cases from the beginning; in all cases after a few years, as efficiency of the production system increases.
- ✓Most or all rainfall is harnessed as effective rainfall, with minimal runoff and soil erosion, leading to longer and reliable moisture regime for crop growth, improved drought proofing, and retention of the upper more-fertile soil layers
- ✓Increase in biological nitrogen fixation (BNF), in soil organic matter at all levels of the root-zone, (possibly sufficient to sequester carbon at depth after root senescence), as well as in CEC, soil moisture holding capacity, soil biota and general agro-biodiversity.

[12] After Pieri, Evers, Landers, O'Connell, Terry: *'No-Till Farming for Sustainable Rural Development'*. WB Agriculture & Rural Devt. Working paper; and authors' own observations.

When increasing areas of land become covered by effective CA, such benefits as listed above extend onwards to the local community and beyond as ecosystem services, and to the three-dimensional catchments in which the farms are located:

5.2 SOME CONSEQUENT IMPACTS AT COMMUNITY OR CATCHMENT LEVEL

- ✓ More constant water-flow in rivers/streams, improved recharge of the water-table/groundwater, with re-emergence of water in dried-up wells and water sources.
- ✓ Cleaner water because pollution, erosion and sedimentation of water bodies are reduced.
- ✓ Less flooding because infiltration increases; less damage from droughts and storms.
- ✓ Improved sustainability of production systems and enhanced food security.
- ✓ Increased environmental awareness and better stewardship of natural resources.
- ✓ Lower costs of municipal and urban water-treatment.
- ✓ Reduced maintenance costs of rural roads.
- ✓ Increased social interactions between members of the local community
- ✓ Improved livelihoods and rural life.

The rate and nature of such improvements due to CA are in positive contrast with what is generally being achieved with 'conventional' tillage agriculture ('TA').

5.3 UNDERLYING THE IMPROVEMENTS

Overall, the characteristics of CA enable it to achieve the amelioration, avoidance, or even reversal, of the detrimental effects of tillage systems across a wide range of places and situations which may differ widely in terms of the characters of the land, of farmers' resources, of social systems and of other factors.

The positive effects at macro-scale derive from the characteristics of the soil when considered as a biological entity at micro-scale (see also 8.2 below).

Two interlinked features distinguish CA from TA:

- Net increase, rather than ongoing decrease, of soil organic matter.
- Improvement in quantities and duration of soil-moisture at plant-available tensions (soil matrix potentials), minimizing effects of atmospheric drought on crops.

Common to both are the need for sufficient nutrients to be available to plants at all times when soil-water supply is not limiting.

Successful and effective CA systems are implemented by individuals' preferences and decisions. An important motivator in many situations is the farmer's wish to restore, and make more productive, farmland which has been damaged (often unknowingly) as a result of tillage agriculture over the years, and thus jointly to benefit the land on the one hand and his/her family's livelihood on the other.

For resource-poor farmers in particular, achieving such soil improvements and benefits may take time to achieve fully, through a series of accumulating small improvements. Measures which enable infiltration of the highest proportion of rainfall and thereby minimize losses of potential soil water, may be a first critical stage, together with P and N additions, in starting the upward spiral of improvement.

6. Hindrances to progress

Main hindrances to faster spread can be listed under the general headings 'Ecological', 'Historical', and 'Intellectual'.

6.1 ECOLOGICAL HINDRANCE

Africa has wide range of agro-ecologic situations across which more secure and more-productive agriculture systems are urgently required. They pose a range of agro-ecologic and/or socio-economic challenges. Can CA's best effects be achieved in every situation?

Agriculture usually aims to provide more of what people prefer than what the undisturbed ecosystems can or could provide, provoking many ecosystem adjustments which are foreseeable but often ignored, and which may have disastrous results if managed inappropriately. Soils already seriously damaged by past mis-management are degraded resources on which to plant present and future crops. Their remediation needs adjustments in management for restoration and sustainability of productive capacity. Improvements in levels of P in the soil assists the establishment of N-fixing leguminous plants – preferably quick-growing and suitably-inoculated leguminous trees in the worst situations. The N fixed in this form is more-efficiently used than that applied 'from the bag', and together with the P, begins the provision of those plant nutrients essential for subsequent crop growth and function – and subsequent build-up of soil organic matter - in such degraded soils.

6.2 HISTORICAL HINDRANCE

Land which has been 'opened' to agriculture for more than a few decades may have had its productive potential significantly reduced by how it has been managed in the past, resulting in increased costs to maintain level outputs, let alone increase them.

In response to demands of rising human populations, land has been 'opened' on a significant scale over more than 150 years from multi-species (vegetation x soil x animal) ecosystems' natural bush/forest to systems based on many fewer species. 'Modern' agriculture has promoted the almost-universal use of tillage equipment, whose use in many situations has been rapidly followed by significant net losses of soil organic matter due to soil disturbance, at precipitous rates initially followed by more gradual further decline from those low residual levels.

The processes, trends and consequences of organic matter degradation, which are seen in both tropical and temperate regions, may be much more pronounced and accelerated in the warm/hot climates of the tropics than where mean temperatures are lower.

6.3 INTELLECTUAL HINDRANCE

Misapprehensions, hallowed by repetition over time, have hindered attempts at avoidance of, and recovery from, damage to land's productivity. Examples include:

- 'Soil erosion' has commonly been assumed to be the culprit for causing yield decline. The 'Battle against erosion', 'Cancer of erosion' etc. approach failed adequately to analyze problems and missed highlighting actual rather than apparent causes.
  This has occasioned much delay and wasted expenditure. In many cases the farmer-led CA revolution began to 'take off' independently over the past thirty years because of dissatisfaction with the relative ineffectiveness of 'conventional' recommendations about Soil & Water Conservation (SWC).
- Concerns about 'soil fertility' are commonly related chiefly to levels of plant nutrients alone and the use of manufactured fertilizers, whereas the phrase 'soil productivity' broadens it to include all features affecting soil as a porous rooting environment, a habitat for soil micro-organisms, and a storage for water and nutrients.
- Many people have a perception that 'agriculture' implies a need for tillage of the soil in order to produce annual and perennial crops. The significant change in attitude required to embrace CA based on no tillage poses an element of resistance to CA's more-rapid spread in some parts of the world.
- Many people seem to accept that soil erosion and surface runoff are apparently unavoidable concomitants of 'normal' agriculture, leading to scepticism that there are solutions to these problems. CA demonstrates that, except in extreme situations, this is not necessarily true.
- The earlier 'high-input / high-output 'Green Revolution' of recent decades in Asia and the heavily mechanized, and energy-, capital- and input-intensive industrialized approach to standardized farming in the developed regions has often been assumed to be the appropriate model for raising and sustaining agricultural productivity on the African continent and across the developing world from now onwards. However,

the Green Revolution's environmental damages – to quality of soils and biodiversity as well as of irrigation waters – appear to have limited its future sustainability. This calls into question its overall validity as a model for sustainable agricultural development both there and elsewhere, even more so when considered against the new 21st century realities of high energy costs, climate change and water scarcity.

- It is an intellectual hindrance that small resource-poor farmers are commonly considered by others as needing teaching different ways of doing things, and that 'outsiders' are the ones with the useful answers. Perceptive experience in the field indicates that farm families are keenly aware of problems and potentials, but are unable to access appropriate or sufficient means of resolving the difficulties. Appropriate assistance may often be related to e.g. availability of small amounts of timely 'seed-finance' to initiate an improvement, and/or the enactment of laws which facilitate needed improvements. It may also involve removal of those laws etc. which are found to inhibit relevant development which farmers themselves wish to undertake by adapting some action or object the better to suit their situation. Non-farm agriculturists and others may need to re-examine commonly-held (but often hidden) assumptions about the lives and livelihoods of the families they profess to serve before being able to arrive at truly-appropriate modes of assistance. Somewhat as Dr Samuel Johnson wrote in the 1700s: "*The use of travelling is to regulate imagination with reality, and instead of thinking how things may be, to see them as they are*".

7. Conservation-effective agriculture in sub-optimal/ problem areas

7.1 LIMITING FACTORS

Areas which are less than optimal for introducing CA (with all three key features working in concert) will have a greater number and/or severity of adverse factors capable of hindering plant production and groundwater recharge.

In sub-humid and semi-arid climatic zones it may not be possible to apply the precepts of good Conservation Agriculture to an optimum because insufficiency of rainfall may severely limit how much biomass can be grown per unit area. On the one hand this limits the quantity of harvestable crops; on the other it also limits the amount of residues which are available to serve both as a protective cover to the soil, a substrate for soil improvement, and simultaneously as a source of fodder for animals and as domestic fuel. Fortunately, under these conditions, the decomposition rates also are often lower. If a compromise between different uses of organic matter can be struck, the benefits of CA become visible, although the increase in soil organic matter is slower than under optimal supply levels.

In more humid areas, while water may not be a serious limiting factor, scarcity of particular plant nutrients may prove to be the more significant factors. Relief of e.g. P-deficiency may enable better crop responses to given levels of other inputs, whether human or mechanical energy, fertilizers, improved seeds, etc. Also in the case of phosphate deficiencies the higher biological activity in the soil under CA can improve the P-availability in the long term.

It is always important to identify what might be limiting factors and then, over time at appropriate intervals, regularly to rank their relative levels of importance, thus noting which require the most urgent attention – realising that, as one is mitigated, another may come to the fore.

It is worth noting that improvement of the organic-matter status and activity in the soil can have multiple positive effects which may alleviate/ eliminate more than one limiting factor at the same time.

7.2 CONCENTRATING SCARCE AVAILABLE RESOURCES

The objectives of improving the soil's content and activity of organic matter remain the same, namely:

- to improve the soil as a rooting-zone for crops;
- for more efficient use of rainfall (a free good) for both crop production and groundwater recharge,
- for more-productive use of labour/energy and applied inputs.

If resources are in short supply – e.g., water, phosphate, manure - it makes sense to concentrate them to adequate levels in limited areas, e.g., at the crop's planting stations, from which the young plants will derive most early benefit, rather than spread widely but sparsely. In drier areas of the African continent, this is illustrated by the plant-production successes of water-collecting 'tassa' or 'zai', into which the limited quantities of available manure and compost are concentrated, and micro-doses of appropriate fertilizers may be locally applied to greatest effect (Figures 9 and 10).

FIGURE 9

[rephotographed from Goddard, Zoebisch, Gan, Ellis, Watson, Sombatpanit, (eds.) 2008. No-till farming systems. Bangkok: World Assoc. Soil & Water Conservation. WASWC Special Publicn. No 3, p.169]

FIGURE 10
"Burkina Faso: zai concentrate water and nutrients"
[rephoographed from Critchley, Reij and Turner, 1992. 'Soil and water conservation in sub-Saharan Africa'. Rome, IFAD. p.47, Fig. 13.]

It is therefore becoming increasingly clear that degraded lands, even in the dry tropics such as Niger (Figure 11), can be rehabilitated and soil productive capacity regenerated by applying the principles of CA as with tassa or zai systems.

FIGURE 11
"Without tassa nothing can be harvested on barren degraded land" (Niger)
[Rephotographed from Hassane, Martin, and Reij, 2000. Water harvesting, land rehabilitation and household food security in Niger'. Rome: IFAD. p.21, Fig. 5]

7.3 REACHING THE GROUNDWATER

The greater the proportion of a field's area or, preferably, of a catchment that is treated with these 'small basins of water concentration', the greater will be the proportion of rainfall captured and infiltrated from the surface down to depth, per hectare of land surface, (rather than running off). Then the greater will be the likelihood of such water as is in excess of crop requirements reaching the groundwater and maintaining or raising the level of the sub-surface water-table, which is tapped by wells and boreholes and which also is the source of streams' and rivers' flows.

7.4 ENHANCING FERTILIZERS' EFFECTIVENESS

It should be noted that in tillage-agriculture situations, while purchased fertilizers alone may be able to raise crop yields significantly where insufficient plant nutrients have been the major limiting factor, they will not, of themselves, result in sustainable improvements in porosity of the soil and hence of soil moisture conditions. For this, adequate supplies of organic matter need regularly to be provided to 'feed' the soil biota, as is the case with 'classic' Conservation Agriculture systems. On the scale of a stream's catchment this is clearly essential in order to maintain the land's ongoing capacities to yield both vegetation <u>and</u> water every year.

7.5 KEEP THE CARBON-GAINS: AVOID TILLAGE

From studies of effects of tillage on oxidation of soil carbon reserves, it becomes clear that, after a net accumulation of organic matter has been achieved in the previous year, a single severe tillage operation could result in the loss by oxidation of much or all the carbon previously gained.

If, for reasons of e.g. soil compaction by animal trampling, it is necessary to disturb the soil again, such disturbance should be as limited as possible – in both area and severity of disturbance - consistent with achieving the required result, in order to safeguard as much of the soil organic matter as possible from being oxidised. The soil aggregates may have taken many months to build up, but their destruction may take only a few days. Strip-tillage between rows of mulch in the crop-lines may be useful in some situations, such as on moist soils under cold climatic conditions: it is preferable to conventional whole-field tillage, but is has some disadvantages compared with no tillage.

7.6 MINIMIZING AREAS OF COMPACTION

If wheeled machinery is to be used in the farming operation and if irreversible soil compaction cannot safely be avoided by lowering the contact pressure on the soil, it is advisable to limit the compaction thus caused into permanent 'tramlines' which are used for every operation, thereby not damaging the surface porosity already achieved on the majority of the area.

8. Thinking unconventionally

It is helpful not to feel completely constrained by the dogma of conventional approaches to problems encountered. A more free-ranging mind may see unconventional possibilities for solving problems. Here are three examples:

8.1 "SOIL EROSION IS NOT CAUSED BY DEFORESTATION, OVERGRAZING, EXCESSIVE CULTIVATION"

Common responses have been to promulgate laws and other pressures on farmers to abandon such practices, but with almost no lasting success. However, by considering three components that all three 'causes' have in common (Figure 12), we can discern other possible ways of tackling the erosion problem.

FIGURE 12
Re-thinking the supposed causes of erosion

> SUPPOSED 'CAUSE'> RELEVANT v COMPONENT v	Deforestation	Overgrazing	Excessive cultivation
Loss of organic matter on and in soil	√	√	√
Loss of soil porosity	√	√	√
Loss of plant cover	√	√	√

8.2 "FOR PURPOSES OF NATURAL RESOURCE MANAGEMENT, SOIL SHOULD BE RE-DEFINED AS A BIOLOGICAL ENTITY – RATHER THAN A GEOLOGICAL ONE"

With respect to management of living natural resources, there is a case to be made for re-defining soil primarily as a biological – rather than a geological – entity. This would focus attention on how best to improve its capacities to yield vegetation and water.

'…Society might take better care of soil if it were considered less as an inorganic physical unit of mineral particles, air, water and nutrient ions that happens to contain life, but more descriptively as a living system, a complex and dynamic subsurface ecosystem of diverse living organisms (including plant roots), non-living organic matter, and biologically-transformed organic/humic products, which inhabits, modifies and interpenetrates an inorganic mix of mineral particles, air, water and nutrient ions, and which changes dynamically over the fourth dimension of time'.[13]

As already indicated, considering soil in this light, and treating it accordingly, can be expected to result in greater profitability of farming enterprises and in rising benefits to the wider society.

Related to this is the concept of 'soil health', of which two similar definitions are given in Annex 1. The definitions are readily compatible with the characteristics and objectives of Conservation Agriculture as discussed in this paper.

8.3 WORKING IN FARMERS' OWN CONTEXTS: DISSEMINATION FOR ADAPTATION OF CA PRACTICES THROUGH FARMER FIELD SCHOOLS

CA is knowledge-intensive farming practice requiring farmers to understand and develop capacity to test and integrate CA principles and practices into their own farming systems to fully harness the benefits offered by CA. Through a Farmer Field School approach, it has been possible to introduce and disseminate appropriate CA practices into many countries across Africa, and there have been notable successes. In the context of a Farmer Field School, individual farmers may prove to be the best judges of what could work best for them to put CA principles into practice in their own particular situations. Farmer Field Schools offer an effective mechanism to set up a process of farmer discovery adoption and adaptation learning in order to accelerate CA's positive impact on livelihoods, food security, economic development and the environment.

[13] Shaxson T.F. 2006. in: *Re-thinking the conservation of carbon, water and soil: a different perspective.* In: Agronomie/Agron. Sust. Dev., 26, 1-9.

9. Key areas for further investigations

9.1 TOPICS COMMON TO ALL CA SYSTEMS.

Topics that are common to all CA systems are:

- *Rebuilding 'last-resort' resistant reserves of s.o.m.:* What is the best way to rebuild s.o.m. reserves with special reference to the more resistant materials which provide stores of organic complexes with nutrient ions that provide 'last resort' provisions before the soil becomes of very little value for plant production?
- *Characterize the changes in relative ranking of limiting factors over the process/sequence of soil improvement:* At a given site where a soil has become degraded, an understanding is important of what is the relative ranking among the biologic, physical, chemical and hydrological factors which currently limit its productivity, so as to know at, a given stage, which to address with priority in actions to improve the situation. This might include some "urgent repair" actions before even starting conversion to CA". Priorities may change as the soil condition improves over time, indicating the nature of what changes in management should follow to optimize the rate of ongoing improvement in soil condition. Undertaking of such investigations in different agroclimatic zones will help to clarify the dynamics of soil improvement as a basis for better-informed decision-making at all levels, from field to national institutions.
- *Characterizing effects of induced changes soil conditions which result in improved infiltration and percolation:* Greater understanding and enlightenment is required of the dynamics of soil water with regard to reaching deeper roots and movement down to groundwater once infiltration capacity through the surface layer has been achieved and safeguarded. This would help to link the interests of farm-families – as both agriculturists and as users of water – and those of the wider society concerned about water reserves and streamflow maintenance. Repeats of soil-water 'tracking' over time, as shown in Fig. 7 (above) would enable effective comparison of relative benefits/dis-benefits of adopting one vs. another strategy for improvement the soil and/or management method

- *Contributions of different types of organic-matter input to soil health conditions*: It is clear that different types of organic matter result in different products of microbial breakdown and transformation (e.g., differences in effects of e.g., leaves of *Tithonia sp.*, wheat straw, cattle manure, charcoal, sawdust, etc.) on soil conditions and plant responses.
- *Identifying readily-usable indicators of agro-ecosystem changes and condition:* Farmers and others will want to know whether their CA systems are improving in soil health and having the expected positive effects as time progresses. Such indicators as changes in weed flora, associations of insect species, associations of micro-organisms, condition of soil architecture, frequency and severity of runoff, could facilitate regular monitoring, enabling the plotting of the trajectories of change as CA's effects intensify.
- *How to integrate cattle and other animals with CA crop-production system?:* Livestock might be a problem since it creates competition for the use of residues as forage. On the other side livestock-keeping provides economic benefits in growing forage crops and with this gives opportunities to diversify crop rotations, which makes them healthier and increases the overall productive capacity of the production system. In what ways can balances be struck between the (complementary) needs for feeding animals and feeding the soil?
- *Appropriate support and assistance to farmers using CA:* When, in a particular country, there is sufficient convincing evidence of the benefits to be derived from its wider spread, what administrative and legal arrangements would best serve to support the initial practitioners as they make the transition from TA to CA but also encourage others to join the CA revolution?
- *Quantify and document rates of CO_2 flux to atmosphere* after differing severities and types of tillage, in different *tropical* situations, in comparison with rates from no-till CA systems in the same regions.

9.2 TOPICS MORE SPECIFIC TO PARTICULAR ENVIRONMENTAL CONDITIONS AND CROP PREFERENCES

Topics that are more specific to particular environmental conditions and crop preferences are:

- *Characteristics of sequences of crops, including green manure/cover crops*, to make up manageable rotations in CA systems for particular localities, e.g., humid/subhumid/semi-arid regions; sandy/clayey/silty soil areas; subsistence farming/market-oriented farming etc.
- *Weed management:* Weed-control poses difficulties in many situations, especially where farmers do not have the resources to buy herbicides and equipment appropriate to their particular situations. Ranges of

strategies need to be available to farmers which are appropriate to the weed flora, the rotational sequence and system, and the farmer's resource endowments. Crop rotations, permanent soil cover and the avoidance of bringing weed seeds to germination are important parts of the weed management strategies under CA.

- *Pest management:* Comparable comments apply in the case of pest management. For both weeds and pests, the concepts and practices of Integrated Weed / Pest Management appear likely to fit well into CA systems.
- *Determine optimum combinations* of soil organic matter x manufactured fertilizers for soil/plant system nutrition in different agro-ecologic situations.
- *Put an economic value on saved rainwater:* Rainwater is assumed to be a 'free good' when programmes and projects are put together and their likely costs and benefits calculated. The change from tillage agriculture (TA) to CA systems can result in prolongation of plant-available soil moisture which can translate into more-secure and potentially higher yields (as shown above). Rainfall may be free at point of entry, but it gains a potential measurable positive value once it is in the reach of crops' roots. By contrast, avoidable runoff - as lost potential soil moisture – can similarly be given a negative value.
- *Ensure appropriate climatic and soil variables are recorded* regularly and in sufficient frequency and detail throughout long-term experiments, as an aid to more-detailed interpretation of results than is possible when such data are not available.

10. Conclusions

10.1 CHANGES

Both Conservation Agriculture and Tillage Agriculture cause soil changes – but in opposite directions.

Benefits of CA reach far beyond minimizing water runoff and soil erosion (though this is often stated as a first reason why farmers adopt it). It has profound ongoing beneficial effects on the soil as a rooting environment and as a receiver, store and downward transmitter of rainwater translating into improved ecosystem services.

The living and non-living components of organic matter together have catalytic effects on the capacity of the soil to provide both vegetation and water. Conversely, insufficiency of organic matter in soils limits soils' productivity and sustainability and diminishes the efficiency of use of applied inputs to agricultural plant/soil systems.

The consequences have positive repercussions on the stability, sustainability and profitability of farming.

10.2 RESPONSE

A response to the challenge of reversing the trend of land degradation is to spread the application of better systems of land husbandry – of which well-managed CA is a prime example - which are capable of reversing these adverse trends and of repairing past damages to ecosystem functions caused by tillage agriculture (TA).

CA, in optimum agro-ecologic conditions, has been demonstrated to be capable of causing this reversal of trends, repairing past damage due to tillage agriculture (whether practised without or with heavy use of agrochemicals and energy), and restoring sustainability to soils' productivity.

The fact that autonomous spread of CA occurs outward from farmers who have already made the transition demonstrates that its benefits are both welcomed and repeatable and that the appropriate CA systems are workable by farmers.

The further spread of CA into a wide range of other agro-ecological situations then depends on understanding the principles which underlie CA's successes, and devising appropriate systems for each new situation, in which the practices enable the principles to have fullest positive effect.

10.3 ILLUMINATIONS

Now it is possible to work with a positive approach:

'How can we make things even better, and in so doing avoid the old problems?' rather than with the old negative approach:

'How can we stop soil erosion?

It is now possible to see:

- How and why well-applied CA works.
- How damaged land can become restored to usefulness and productivity.
- Why and how mismanaged soils degrade.
- How long bush fallows used to have their positive effects in extensive low-intensity agricultural systems, and why short breaks of recuperative grass were important (though not necessarily sufficient) in conventional tillage-agriculture systems.
- Why 'soil erosion' is a consequence, not a primary cause, of soil degradation.
- Why soil 'in good condition' limits the duration of climatic drought's effects.

v What is the real basis of sustainability in agriculture?

10.4 GREEN REVOLUTION, BLUE REVOLUTION

Following its many and widespread successes, the Green Revolution of the 1960s and 1970s based on HYVs and high inputs of fertilizer, pesticides and irrigation water appears to have reached plateaux of crop production, partly, at least on account of degradation of soil and water resources.

Conservation Agriculture appears to have the capacity also to raise but also stabilise yields, to restore productivity of damaged soils, and to improve supplies of usable water. Because water is likely to become increasingly scarce with respect to rising demands, perhaps CA deserves to be called the coming 'Blue Revolution'.

10.5 THINK LIKE A ROOT, LIKE A RIVER

Perceiving the soil as a *biotic* entity encourages thinking about not only soil organic <u>matter</u> but also soil biotic <u>processes</u>. Broadening this to considering how these are linked with catchments' yields of plants and of water also suggests '*Think like a root; think like a river*' as a way of working out what features of the soil in a particular situation would be most appropriate for <u>both</u> those yields to be achieved on a recurring basis. If, when both need improvement, they are treated only as separate subjects there is danger that the solutions proposed for one problem – poor crop yields – may become problematic for the achieving; other – water yields, and *vice versa*. This takes you back into the body of this paper with its pointer that, in particular, the porosity of soil and how that is improved and maintained is a key to ameliorating both problems together. For example, construction of big dams as a solution to water-shortage problems almost always has been without giving timely prior attention to improving the conditions of the soil in the catchment, with consequent resulting loss of capacity by sedimentation much faster than assumed. Conversely, application of unnecessarily high quantities of mineral fertilizers to croplands which have poor and unimproved porosity can result in pollution of the streams that flow from the catchment to which they were applied.

10.6 REPLACING THE 'TILLAGE PRESUMPTION'

The successes of well-managed Conservation Agriculture systems point to the occurrence of a positive revolution in practice, behind which is the revolution in thinking on the part of the farmers involved, and on the part of those who assist and advise them. While much of 'the message' spreads farmer-to-farmer within and between generations, this is not yet necessarily, nor automatically, so in the case of those institutions responsible for pre-and in-service training of future advisers and others serving the farmers. The concepts, key components and effects of Conservation Agriculture need now to form the core of such training, such that the 'tillage presumption' no longer occupies that upper position.

10.7 REDUCING THE REASONS FOR FIGHTING OVER ACCESS TO WATER AND LAND

The widespread adoption of CA principles and practices will make positive contribution to food supplies and food security and to the greater availability of clean water in groundwater and streams. This will delay and minimize the pressures to fight over access to farmland and water supplies as adverse effects of both population increase and climate change together put increasing pressures on these vital resources.

10.8 GOOD LAND HUSBANDRY

Well-managed and effective systems of conservation agriculture provide excellent examples of good land husbandry, of which a prime effect is re-vitalisation and maintenance of soil health for crop intensification and ecosystem services. The excellent soil conditions which can develop and be maintained with well-managed conservation-effective agricultural systems provide the criteria against which all other forms of soil management should be compared.

11. Envoi

'Such people [are] driven by a desire to make no-tillage as sustainable and risk-free as possible, and in the process make food production itself sustainable for the first time in history. … The results have been significant and will have far-reaching consequences[14].

[14] Baker, Saxton, Ritchie, Chamen, Reicosky, Ribeiro, Justice, Hobbs, (2007): No-tillage Seeding in Conservation Agriculture – Second edition. FAO and CABI. The dedication note.

ANNEX 1
Soil health

While there is much talk of 'soil quality' as if it were a static and sufficient characteristic, there is less-frequent mention of 'soil health', referring particularly to the biological dynamics of soil quality.

"*Below are 1) the ideas of David Wolfe at Cornell University and 2) Peter Trutmann's comments on Doran and Zeiss' definition of soil health that appeared in Applied Soil Ecology (15:3-11) during 2000:*
'1) Soil health refers to the integration of biological with chemical and physical approaches to soil management for long term sustainability of crop productivity with minimal impact on the environment. "Healthy" soils maintain a diverse community of soil organisms that: help to control plant disease, insect and weed pests: form beneficial symbiotic associations with plant roots (e.g., nitrogen fixing bacteria and mycorrhizal fungi); recycle essential plant nutrients; improve soil structure (e.g., aggregate stability) with positive repercussions for soil water and nutrient holding capacity; and ultimately improve crop production. Examples of management practices for maximizing soil health would include: maintaining vegetative cover on the land year-round to increase organic matter input and minimize soil erosion; more reliance on biological as opposed to chemical approaches to maintain crop productivity (e.g., rotation with legume and disease-suppressive cover crops); and avoiding use of heavy equipment on wet soils to avoid soil compaction.
David W. Wolfe, Ph.D.
Professor, Dept. of Horticulture
Cornell University
Ithaca, NY

'2) *Soil health is the capacity of soil to function as a vital living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health* (Doran and Zeiss, 2000, Applied Soil Ecology 15:3-11). This definition indicates need of the soil to function as a vital living system to sustain biological productivity, promote environmental quality and maintain plant and animal health. To us 'soil health' emphasizes a unique property of biological systems, since inert components cannot be sick or healthy. Management of soil health thus becomes synonymous with 'management of the living portion of the

soil to maintain the essential functions of the soil to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health'.
Dr. Peter Trutmann
Director
International Integrated Pest Management
Cornell University
Ithaca, NY 14853-4203"
Both statements dated 2000 or later.
From: http://ppathw3.cals.cornell.edu/mba_project/moist/TropSCORE.html (seen Feb. 23rd, 2008).'Worldwide Portal to Information on Soil Health' Homepage Index 1C. TropSCORE –The Consortium for Tropical Soil Cover and Organic Resources http://www.agnic.org/

ANNEX 2
A few, out of many, titles of additional relevant references

Bationo A, Khara J, Vanlauwe B, Waswa B and Kimetu J (2006). *Soil organic carbon dynamics, functions and management in West African agro-ecosystems.* In: Agricultural Systems (2006 – in press). Elsevier.

Bationo A. et *al*. (2007). Lessons *learnt from Long Term Experiments in Africa*. In: Symposium Abstracts: Innovations as Key to the Green Revolution in Africa. Arusha, Tanzania. Eds. Bationo, Okeyo, Waswa, Mapfumo, Maina and Kihara. p.32.

Buerkert A, Bationo A, and Dossa K (2000). *Mechanisms of Residue Mulch-Induced Cereal Growth Increases in West Africa.* Soil Sci. Soc. America J. 64:346-358

Denef K, Zotarelli L, Boddey RM, Six J (2007) *Microaggregate-associated carbon as a diagnostic fraction for management-induced changes in soil organic carbon in two Oxisols*. *Soil Biology & Biochemistry* 39**:** 1165-1172.
Gale WJ and Cambardella CA (2000). *Carbon Dynamics of Surface Residue and Root-derived Organic Matter under Simulated No-till*. Soil Sci. Soc. America J., 64: 190-195.

Goddard T, Zoebisch M, Gan Y, Ellis W, Watson A and Sombatpanit S (eds.) (2008). *No-Till Farming Systems*. World Assoc. Soil & Water Consn. Special Publicn. No. 3. ISBN 978-974-8391-60-1. 539pp.

Kibunja CN, Mwaura FB, Mugendi DN, Wamae DK and Bationo A (2007). *Long term land management effects on crop yields and soil properties in the sub-humid highlands of Kenya*. In: Symposium Abstracts: Innovations as Key to the Green Revolution in Africa. Arusha, Tanzania. Eds. Bationo, Okeyo, Waswa, Mapfumo, Maina and Kihara. p.34.

Kimetu JM, Lehmann J, Mugendi DN, Bationo A, Verchot L and Pell A (2007) *Reversal of productivity decline in agroecosystems with organic amendments of differing stability*. In: Symposium Abstracts: Innovations as Key to the Green Revolution in Africa. Arusha, Tanzania. Eds. Bationo, Okeyo, Waswa, Mapfumo, Maina and Kihara. p.39.

Ouattara, B., Ouattara, K, Serpantieé, G, Mando, A, Seédogo, MP and Bationo, A (2007)._*Intensity of cultivation induced effects on soil organic carbon dynamic in the western cotton area of Burkina Faso*. In: Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities. Netherlands: Springer.

Saturnino, H.M. and Landers, J.N. (eds). (2002). *The Environment and Zero Tillage*. Brasilia: APDC & Rome: FAO of UN. 144pp.

Six J, Elliott ET, Paustian K (2000) *Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture*. Soil Biology and Biochemistry 32**:** 2099-2103

Zotarelli L, Alves BJR, Urquiaga S, Boddey RM, Six J (2007) Impact of tillage and crop rotation on light fraction and intra-aggregate soil organic matter in two Oxisols. Soil & Tillage Research 95: 196-206.

Appendix 2

Technical Workshop, FAO, Rome: 22-24 JULY 2008
Philippines Room C277

Investing in sustainable crop intensification: The case for improving soil health technical background[15] & agenda

"Despite the artistic pretensions, sophistication and many accomplishments of mankind, we owe our existence to a six-inch layer of topsoil and the fact that it rains".

Pinned on Don Meyer's office wall /? Confucius

1. PRESSURES AND PROBLEMS

With growing human populations and ever-more limited areas of land suitable for lateral expansion of agriculture, higher production of vegetation per unit area is essential for future security of food and other agricultural products.

At the same time, water supplies are becoming less reliable. Plant growth, streamflow and groundwater availability are being adversely affected, situations which climate changes are likely to worsen.

In the majority of rainfed areas of the tropics and subtropics, the agricultural productivities of soils, of water, of nutrients, and hence of the rural livelihoods that depend on them, are not being sustained. For those already poor, their livelihoods are becoming increasingly insecure.

There is evidence - from both temperate and tropical regions – that, after clearing of undisturbed vegetation, whether in the recent or distant past, organic matter in the soil declines at first rapidly and then, over many decades, more slowly to very low levels if insufficient regular additions of organic

[15] Complementing '*Background*' in the TAA et al. Workshop Record, Newcastle University, 30-31 March 2007.

(carbon-based) materials are not regularly returned. Associated with this are depletions of nutrient reserves and of soils' capacities to store soil moisture, resulting in decline in underlying production potentials.

This has been known for long by soil specialists but was never mainstreamed into development initiatives. Thus, techniques adopted for reducing rates of productivity loss or countering rising costs of maintaining average yields, avoiding soil erosion and minimizing flooding, have in many cases proved to be insufficiently effective. Production can thus prove unsustainable under 'conventional' practices plus commonly-recommended 'add-ons' such as some of the techniques aimed at soil and water conservation.

Merely proposing 'strengthening' conventional approaches, with or without improved plant genetic resources, is unlikely to remedy such a situation on lasting basis.

2. PRINCIPLES OF SOIL HEALTH FOR PRODUCTIVITY

From many physical landscapes, we expect the three-dimensional catchments which are clothed in soil to yield sufficient crops and other vegetation of various types and, simultaneously, volumes of clean water from streams and boreholes regularly on a repeated annual basis.

Plants, rivers and groundwater depend on water penetrating into soil which is porous from the surface downwards. Insufficiency of water for plants hinders the interacting functioning of the other components of soil productivity: biological, physical, and chemical.

The rate of entry of water into and through soil is governed by soil's porosity, which in turn is governed by the volume and inter-connectedness of pores able to transmit water. The volume and availability of water which plants can use is determined by the proportion of soil pores which can retain water against the force of gravity and yet can release that water in response to 'suction' exerted through roots as dictated by the plants' physiology and atmospheric demand.

Insufficiency of water and/or of various nutrients required by plants for growth processes diminish the derived productivity of the soil in which they are growing, inhibiting full interactions in the plant-soil system. Inadequacy of plant nutrients hinders plant growth and development; severe water-stress stops the whole system.

Soil porosity is damaged or destroyed by compaction, pulverisation, and/or collapse due to degradation and loss of organic matter. Net loss of organic matter is caused by tillage of the soil, which results in accelerated oxidation of the carbon in the materials to carbon dioxide gas and its loss to the atmosphere.

Following such damages, appropriate soil porosity is regained and maintained chiefly through biotic transformation of the non-living fraction of organic matter by its living fraction - soil-inhabiting fauna and flora - from micro-organisms such as bacteria to macro-organisms such as worms, termites and plants themselves. Their metabolic activity contributes glue-like substances, fungal hyphae etc. to the formation of irregular aggregates of soil particles, within and between which are the all-important pore-spaces in which water, oxygen and carbon dioxide flow and roots grow. These substances also contribute markedly to the soil's capacity to capture and retain nutrient ions on organic complexes, and provide a slow-release mechanism for their liberation back into the moisture in the soil. For this activity and its effects to be maintained, a sufficient supply of new organic matter needs always to be available as a source of energy and nutrients to the soil organisms – not just to the plants alone.

If the conditions are kept favourable for biotic activity in the soil, this dynamic process of formation and re-formation of the porous soil architecture will continue from year to year, maintaining the capacities of landscapes thus treated to continue yielding vegetation and water on a recurrent basis, contributing to sustainability of such production processes.

Here lies the significance of maintaining 'soil health'. For the purposes of deciding how best to manage the land to maintain its productivity, it is more appropriate to think of the soil primarily as a living biological entity interpenetrating the non-living components, and forming from the top downwards, rather than as a geological entity forming from the bottom upwards with living things in it at the top.

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Definition of 'Soil Health'[16]

Soil health is the capacity of soil to function as a living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. It emphasises a unique property of biological systems, since inert components cannot be sick or healthy.
Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots (e.g., nitrogen-fixing bacteria and mycorrhizal fungi); recycle essential plant nutrients; improve soil structure (e.g., aggregate stability) with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production.

[16] Derived by combining Doran and Zeiss; Wolfe; Trutmann, quoted together on http://ppathw3.cals.cornell.edu/mba_project/moist/TropSCORE.html

Examples of management practices for maximising soil health would include maintaining vegetative cover on the land year-round to increase organic matter input and minimize soil erosion, more reliance on biological as opposed to chemical approaches to maintain crop productivity (e.g., rotations with legume and disease-suppressive cover crops), and avoiding physical (mechanical) interventions which might compact, alter or destroy the biologically-created porous structural arrangements of soil components.

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3. PUTTING PRINCIPLES INTO PRACTICE WITH CONSERVATION AGRICULTURE ('CA')

A growing number of farmers – on large and small farms in a rising number of countries – have successfully been developing crop-production systems which satisfy three important conditions favourable to biotic activity in the soil: (a) permanent cover of the soil with organic matter provided by a mulch of retained residues from the previous crop or fallow and by living cover-crops; (b) minimal soil disturbance by tillage, and preferably no tillage once the soil has been brought to good condition; (c) rotation of crops, (to include N-fixing legumes) which contribute to maintaining biodiversity above and in the soil and avoid build-up of pest-populations within the spectrum of soil inhabitants.

The generic name commonly used for such systems is 'Conservation Agriculture', in which the rate of accumulation of organic matter consistently exceeds the rate of its loss, and as such clearly distinguishes it from 'conventional' tillage agriculture ('TA').

Benefits which attract people at farm level include[17]:

- Labour, time and farm power are saved through reduced cultivation and weeding requirements.
- Lower variable costs because both operations and external inputs are reduced.
- Mechanical equipment has a longer life-span, lower repair costs, and consumes less fuel than with tillage agriculture.
- Less movement of machinery and equipment necessary in the field; less drudgery of repetitive work.

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[17] After Pieri, Evers, Landers, O'Connell, Terry: 'No-Till Farming for Sustainable Rural Development'. WB Agriculture & Rural Development. Working paper; and authors' own observations.

[18] In situations where farmers are at 'starting points' with regards to fertilizer use, the productivity of applied nutrients with CA increases dramatically, thus creating more incentives for smallholder farmers to increase their very low use of fertiliser, especially P which is limiting in many soils.

- More stable yields, particularly in dry years because more nutrients and moisture are available to the crops.
- Labour savings provide opportunities for diversification of enterprises and into other activities.
- Yields are increased even as inputs decrease, including lesser inputs of energy, lower demand for pesticides and lower demand for fertilizer although accompanied by greater unit efficiency of those which are applied[18].
- Increased profits, in most cases from the beginning, in all cases after a few years, as efficiency of the production system increases.
- Most or all rainfall is harnessed as effective rainfall, with no runoff and no soil erosion, leading to longer and reliable moisture regime for crop growth, and improved drought proofing.
- Increase in biological nitrogen fixation, soil organic matter and carbon sequestration, cation exchange capacity, soil moisture-holding capacity, soil biota and general agro-biodiversity.

When increasing areas of land become covered by effective CA, these benefits extend onwards to the local community and beyond as ecosystem services, and to the three-dimensional catchments in which the farms are located:

- More constant water-flow in rivers/streams, improved recharge of the water-table/groundwater, with re-emergence of water in formerly dried-up wells and water sources / courses.
- Cleaner water because pollution, erosion and sedimentation of water bodies are reduced.
- Less flooding because infiltration increases; less damage from droughts and storms.
- Improved sustainability of production systems and enhanced food security.
- Increased environmental awareness and better stewardship of natural resources.
- Lower costs of municipal and urban water-treatment.
- Reduced maintenance costs of rural roads.
- Increased social interactions between members of the local community
- Improved livelihoods and rural life.

The rate and nature of such improvements due to CA are in positive contrast with what appears to be being achieved with conventional tillage agriculture (‘TA’).

4. SOIL HEALTH AND CONSERVATION AGRICULTURE

Present-day scarcities of food, other agricultural products and water, relative to ongoing and rising demands, are exacerbated by the poor condition of landscapes which yield them. In many parts of the world soils are acknowledged to be sick, in poor health, and falling in potential for self-sustaining productivity.

The similarity of this observation regarding soils with that of public health within humanity is strong. In terms of productive capacity: those in poor health function below potential and in various ways impose costs on those who rely on them. The capacity of both soils and people to continue functioning over time depends on the repetitive life-processes which give the capacity of cells to replicate, and thus continually to regenerate the body and to maintain its functions. They require regularly-repeated supplies of energy and nutrients which derive from photosynthesis by plants, from the capture and recycling of nutrients derived from geological processes, and on non-limiting supplies of water. Seen in this light, potentially-productive soils should properly be considered as biological entities rather than as geological residues.

While there is much talk of 'soil quality' as if it were a static and sufficient characteristic, there is less-frequent mention of 'soil health', referring particularly to the biological dynamics of soil quality. (A relevant definition of Soil Health has been given above).

If plants we see above-ground don't thrive because soil is in poor condition, then probably the life below ground doesn't thrive either (= is 'sick'), for the same reasons, jeopardising the effectiveness of the mutual interdependence of the above-and below-ground parts of the soil/plant system. It is easy to see the symptoms above-ground, but more difficult (as yet) to discern and characterize them below the surface.

Soil in 'good condition' (static) or 'good health' (dynamic) benefits from the following:

(a) *Buffering against direct impacts* of solar radiation (esp. UV) and rainfall impact. It also needs: a substrate for (i) organic (= chemistry of carbon compounds) activity, especially re organic glues in soil architecture (the integral matrix of solids + spaces); (ii) the de-composition of raw carbon-rich materials by soil organisms, to provide plant-available nutrient reserves and to enhance soil's cation exchange capacity (CEC) for their retention and slow-release. In addition, crops need least competition from weeds.

Provided by **cover of organic matter** (esp. crop residues) over the soil surface.

(b) *Minimum disturbance of optimum soil architecture* once it has been achieved. This maintains optimum gaseous balance (esp. O_2:CO_2) in the porous matrix of the rooting-zone, limiting any accelerated oxidation and thus unduly-high rate of loss of soil organic matter, as well as maintaining soil porosity for water-movement, retention and release at all scales. It also minimizes digging-up buried, dormant weed seeds, again minimizing competition from them.

Provided by using **zero-tillage** systems.

(c) *Significant supply of N for plant-processes,* to the extent possible/feasible by biological N-fixation, because of (i) minimal cost of provision (the N-fixing bacteria do it for free), (ii) prolonged availability in slow-breakdown/release organic molecules/compounds.

Provided by crop systems which include **legumes**.

(d) *Varied mixtures in crop-sequences* for several purposes: (i) cover; fodder; range of marketable species; (ii) varied rooting depths re greater access to water, nutrients; (iii) soil-improvement by organic-matter additions at all depths reached; (iv) avoiding build-up of pests, diseases (both above and below the surface) to damaging levels, by interrupting their life-cycles; and, by smothering them, also minimizing competition from weeds.

Provided by **crop rotations.**

The combination of these four requirements can be provided by the four features which characterize mature well-managed **Conservation Agriculture** systems, the focus of this Workshop.

5. THE CHALLENGE: MAINSTREAMING CONSERVATION AGRICULTURE

In some countries such systems which improve soil health and increase efficiency of factor-use in agriculture are now widespread across both varied types of country and varied types and sizes of farms. They have become established despite initial resistances -- intellectual, administrative, and financial -- which have gradually been overcome by persistence which built up sufficiently striking examples of success to reach the point of ultimate convincement of the doubters. Ultimately 'a fair wind'- of increasing facilitation and assistance to those who then wanted to start - also developed.

However, to move from conventional tillage agriculture to effective CA requires much alteration in conventional thinking and attitudes about how agriculture should be undertaken not only on the part of the farmers but also of policy-makers, scientific experts and advisory staff. Retaining crop residues as mulch, using unfamiliar crops in rotation, changes in needed equipment etc., all may pose great operational and financial uncertainties to farmers, some of whom may nevertheless decide to start out without important e.g. advisory support or appropriate legislation to facilitate the transition. Others may be less bold and watch how their innovative neighbours fare before 'making the jump' Nevertheless systems of CA have been 'catching-on' surprisingly rapidly, much of it through farmer-to-farmer contact.

However, in light of the problems increasingly posed by the combination of climate change, population increase, soaring food prices, and energy and production input costs to restoring, increasing and sustaining the productivity of land for vegetation and water, such systems deserve more than just tacit acknowledgement and approval.

The potential of CA to reverse decline in soil conditions and make production more secure is so significant a factor that farmers in any situation deserve to be encouraged and supported in practical ways to start and complete the transition to CA, to the benefit of themselves, their local and national communities, and to the on-coming generations.[19]

For this to be achieved, long-hallowed assumptions about agriculture and soils themselves may need to be re-examined as a basis for making appropriate improvements to their management. Then, appropriate support capacity needs to be brought together, and integrated into multi-faceted and co-ordinated initiatives among policy-makers, financial institutions, the private sector, administrators, research institutions, advisory and knowledge exchange bodies, and others, in response to the key requirements of, and in closest collaboration with, the members of 'the front line' – the farmers.

6. WORKSHOP OBJECTIVES

Following recommendations made at the conclusion of initial Worksop at Newcastle University, UK, on 30 and 31 March 2007, the organizers of this Workshop have invited stakeholders concerned with agricultural development in the tropics, subtropics and elsewhere to consider the demonstrated potentials of Conservation Agriculture (CA) to improve soil health, and hence productivity and sustainability, as a basis for crop and agriculture intensification and managing ecosystem services. The Workshop objectives are:

1. To describe the principles of Conservation Agriculture and demonstrate its benefits for farmers and societies to widen attention of potentially-supportive decision-makers in the broad fields of Field Practice & Development; Science & Technology, and Policy & Financing.

[19] See e.g. the Millennium Ecosystems Assessment 'Living beyond our means' at http://www.millenniumassessment.org/documents/document.429.sapx.pdf; '*Global Enviroment Outlook–GEO 4* at http://www.unep.org/geo/geo4/report/GEO-4_Report_full_en.pdf; also World Development Report 2008: Agriculture for Development at http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/EXTWDR2008/0, contentMDK:21410054~menuPK:3149676~pagePK:64167689~piPK:64167673~theSitePK:2795143,00.html

2. To discuss, suggest and agree the chief forms of interlinking decisions and action which would provide positive encouragement of, and support to, farmers to make and sustain their transition to beneficial CA systems as most appropriate to their different agro-ecological and socio-economic situations;
3. To pave the way for comparable forums to develop and function at continental, national and local levels;
4. To favour the development of an inter-connected ‘Community of Practice’ around the subjects pertaining to and the benefits deriving from Conservation Agriculture.

WORKSHOP AGENDA

22-24 JULY 2008, FAO, ROME

Day 1: 22 July 2008 (Tuesday)
BLOCK I
Presentation of Evidence of Successful Adaptation, Adoption and Spread of Conservation Agriculture in Different Developing Regions

08:30-09:00 Registration

09:00-09:45 **Session I: Chair: Andrew Bennett**
Opening Session:
i. Welcome: **James Butler (Deputy Director General, FAO)**
ii. Background to the Workshop; Objectives of the Workshop, Process & Agenda, Expected Outcome: **Francis Shaxson**

09:45-10:30 **Session II: Chair: Andrew Bennett**
Global overview presentation on Soil Health and Conservation Agriculture: setting the scene: **Theodor Friedrich**
Rapporteurs: Andrew MacMillan & Norman Uphoff

10:30-11:00 *Coffee Break*

11:00-12:30 A range of cases from each region (20 min presentation, 10 min discussion each case) of evidence of successful adaptation, adoption and spread of Conservation Agriculture in different regions
Session III: Chair: Ivo Mello
Conservation Agriculture cases from Latin America
Brazil: Ademir Calegari
Paraguay: Rolf Derpsch
Argentina: Andres Silvestre Begnis
Rapporteurs: Roberto Diaz-Rossello, Paolo Galerani
Drafting Team Liaison: Bob Boddey

12:30-14:00 *Lunch break*

14:00-15:30 **Session IV: Chair: Mark Holderness**
Conservation Agriculture cases from Asia

China: Gao Huanwen
Kazakhstan: Murat Karabayev
North Korea: Kim Kyong Il & Kim Chol Hun

Rapporteurs: Long Nguyen, Fares Asfary
Drafting Team Liaison: Pal Singh

15:30-16:00 *Tea break*

16:00-18:30 **Session V: Chair: Andre Bationo**
Conservation Agriculture cases from Africa
Cases from Africa: Bernard Triomphe, Saidi Mkomwa & Josef Kienzle
Kenya & Tanzania: Barrack Okoba & Wilfred Mariki
Tunisia: Moncef Ben-Hammouda
Swaziland: James Breen
Madagascar: Jean-Louis Reboul

Rapporteurs: Reynolds Shula, Rachid Mrabet
Drafting Team Liaison: Patrick Gicheru

Notes:

a. Chairs plus Rapporteurs from Sessions II to V: sum up, make first proposals for issues.
b. Working Groups the next day: to note specific issues for their Working Groups; plenary (Session IX & X) may identify more issues for each session.
c Posters, slides, PowerPoints, video and audio recordings of farmers' testimonies and/or time-sequences of changes of farms, fields, landscapes could be brought along and shown in the evenings of Days 1 and 2, and during session XIV on Day 3.
d. Guidance to Case Presenters on Day 1, Conveners and Rappporteurs, and Drafting Team Liaison is given in the Overview section above.

Day 2: 23 July 2008 (Wednesday)
BLOCK II

Three Investment Working Groups: (i) Field Practice & Development; (ii) Science & Technology, (iii); Policy & Financing, to discuss: (a) Principles, issues (including cross-cutting) & gaps; (b) Opportunities for investment; (c) Cross-sector 'knowledge brokering'; (d) Contribution to an Action Plan (including next steps)

09:00-09:30 **Session VI: Chair: Amir Kassam**

Explanation of the objectives and arrangements of the three parallel prime-topic Working Group sessions: **Francis Shaxson & Theodor Friedrich**

09:30-10:30 **Session VII: Three Parallel Working Groups** -- Three primary topics: Field Practice & Development; Science & Technology; Policy & Financing.

Field Practice & Development Working Group:
Co-Conveners: Martin Bwalya & Mark Laing
Rapporteurs: Rabah Lamar, Finton Scanlan, Keith Virgo
Drafting Team Liaison: John Ashburner

Science & Technology Working Group:
Co-Conveners: John Dixon & Nuhu Hatibu
Rapporteurs: Sayed Azam-Ali, Patrice Guillaume, Robert Abaidoo
Drafting Team Liaison: Pat Wall

Policy & Financing Working Group:
Co-Conveners: Norman Uphoff & Richard Mkandawire
Rapporteurs: Jennie Barron, Martin Rokitzki, Lamourdia Thiombiano
Drafting Team Liaison: Deborah Bossio

Notes: a. Participants: public, private and civil society stakeholders generalised/mixed across three prime interests/topics (Field Practice & Development; Science & Technology; Policy & Financing)

b. For each prime topic, the Working Group to discuss and identify:

i. Principles, issues (including cross-cutting) & gaps
ii. Opportunities for investment
 - providers of opportunities
 - investors in the opportunities
iii. Cross-sector 'knowledge brokering'
iv. Contribution to an Action Plan

10:30-11:00 *Coffee break*

11:00-13:00 **Session VIII:** Parallel Working Group sessions continue as above (including preparing draft reports)

13:00-14:00 *Lunch break*

14:00-15:30 **Session IX: Chair: Will Critchley**
Presentation and plenary discussion of reports of Working Groups on Field Practice & Development, and Science & Technology (45 min each)
i. Principles, issues (including cross-cutting) & gaps
ii. Catalogue of opportunities
iii. Cross-sector 'knowledge brokering'
iv. Expressions of interest/commitments to an Action Plan

15:30-16:00 Tea break

16:00-16:45 **Session X: Chair: Rolf Derpsch**
Presentation and plenary discussion of report of Working Group on Policy & Financing (i. – iv. as in Session IX) (45 min)

Notes: Action Plan Drafting Team to draft Action Plan in light of the regional presentations on Day 1 and Working Groups' presentations on Day 2 (to work after hours in Nigeria Room C215) **(Drafting Team Coordinator: Andrew MacMillan)**

Day 3: 24 July 2008 (Thursday)
BLOCK III
Three Working Groups to Discuss the draft Action Plan, and Adoption of the Action Plan

09:00-09:30 **Session XI: Chair: Francis Shaxson**
a. Presentation of first draft of Action Plan: **Andrew MacMillan**
b. Explanation of the objectives and arrangements of the three
Working Group: **Amir Kassam & Theodor Friedrich**

09:30-11:00 **Session XII: Three parallel Working Groups to discuss draft Action Plan;** each Group specifically focussed on a prime topic (Field Practice & Development; Science & Technology, Policy & Financing):

Field Practice & Development Working Group:
Convener: Bernard Triomphe
Drafting Team Liaison: John Ashburner

	Science & Technology Working Group: **Convener: Des McGarry** **Drafting Team Liaison: Pat Wall**
	Policy & Financing Working Group: **Convener: Simon Hocombe** **Drafting Team Liaison: Deborah Bossio**
Notes:	a. Participants in each group: by common interest/ specialization in the specific topic (Field Practice & Development, Science & Technology, Policy & Financing) b. Each Working Group to review: how can each of the primary topics, as represented by that particular topic-group, contribute to the Action Plan?
11:00-11:30	*Coffee break*
11:30-13:00	**Session XIII: Convener: Norman Uphoff** Working Group presentations and plenary discussion (30 min each Group) on the revisions to the draft Action Plan
13:00-14:00	*Lunch*
14:00-15:30	**Session XIV: Convener: Long Nguyen** Poster presentations from participants. (Action Plan Drafting Team to consolidate and finalize the Action Plan)
15:30-16:00	*Tea break*
16:00-17:00	Session XV: **Convener: Andrew MacMillan** Adoption of the Action Plan
17:00-17:30	Closing session: **Eric Kueneman**

APPENDIX 3

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An international technical workshop. Investing in sustainable crop intensification
The case for improving soil health

This publication is a report of a Workshop that brought together people from a wide range of institutions - farmers, researchers, extensionists, policy makers, donors – from 40 countries who share a common concern about the non-sustainability of ways in which farm land is now being used and who are convinced that this must change. The Workshop focused on the growing evidence of success in the adoption and spread of Conservation Agriculture (CA) systems in developing countries. CA-based approaches to sustainable production intensification are highly relevant to the global response to rising food and energy prices, increasing soil and environmental degradation, pervasive rural poverty, climate change and increasing water scarcity. The main outcome of the Workshop is *'A Framework for Action'*. reflecting on actions that would help to upscale the take up of CA, thereby enabling land to be farmed more productively, profitably and sustainably.

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