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Policy Support Guidelines for the Promotion of Sustainable Production Intensification and Ecosystem Services

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Policy Support Guidelines for the Promotion of Sustainable Production Intensification and Ecosystem Services

Programme Social and Environmental Standards

PLANT PRODUCTION AND PROTECTION DIVISION
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FOREWORD

The old paradigm of agriculture, originating from the Green Revolution, that asserts that intensive and productive agriculture must go along with ecological degradation as unavoidable side effects, is increasingly being replaced by a new paradigm of "sustainable intensification". This new paradigm results from the undisputed need to increase agricultural production in order to serve future generations with food, feed and industrial raw materials. But it recognizes at the same time that mankind, if it wants to survive, has to recover the natural resource base and stop environmental degradation, so that the agricultural land use does not only result in the provision of above biological goods, but also in the delivery of environmental services, enhancing the functions of ecosystems and agricultural landscapes in the provision of services essential for survival, such as clean water and air, but also biodiversity.

During the past 50 years, ideas about how to achieve such "sustainable intensification" have matured from concepts to reality. Today we have at our disposal concepts and technologies, how intensive and highly productive and efficient agriculture can be combined in practice and on real farms with the enhancement of ecosystem services but without "trade-offs" or "unavoidable damages", opening up the chances for farmers to receive payments not only for their produce, but also for such services, as for example the sequestration of carbon in the soils or the provision of clean water, using healthy and biologically active soils as medium for such ecosystem functions and services.

This type of farming, commonly known as Conservation Agriculture, is actually applied on about 10 percent of the world's cropland and adoption is growing fast. However, it is not growing fast enough to face the challenges ahead, such as the need to eradicate hunger and food insecurity for a growing population and to address the threats of climate change, land and environmental degradation, resource scarcity and increasing cost of food, production inputs and energy.

For "sustainable intensification" strategy as being implemented through Conservation Agriculture to spread faster, it needs not only the accurate application of the concept and principles, but also supportive policies that can facilitate adoption of Conservation Agriculture and reward the adopters for example with payments for environmental services.

The present publication provides guidance on such supportive policies, as well as on protocols which would be needed to support schemes of payments for environmental services. It is based on actual field experiences of FAO and GIZ in the promotion of Conservation Agriculture in different world regions and is directed specifically to decision makers in governments for designing and implementing agricultural policies and regulations for sustainable development.

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The final draft of the report was formatted for publication by Ms. Magda Morales, and its publishing was facilitated by Wolfgang Prante who is responsible for oversseing the Integrated Crop Management series of AGP. Their help is gratefully acknowledged.

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ACRONYMS AND ABBREVIATIONS

ACT	African Conservation Tillage network
ACSAD	Arab Center for the Study of Arid Zones and Dry Lands
AGRITEX	Agricultural, Technical and Extension Services Department
AMID	Ministry of Agriculture, Mechanization and Irrigation Development
ARC	Agriculture Research Council
AU	African Union
CA	Conservation Agriculture
CAADP	Comprehensive African Agriculture Development Programme
CADS	Cluster Agriculture Development Services
CAPNET	Conservation Agriculture Promotion Network
CATF	Conservation Agriculture Task Force
COMESA	Common Market for Eastern and Southern Africa
Contill	Conservation Tillage
CTDT	Community Technology Development Trust
CIMMYT	International Wheat and Maize Improvement Centre
EMA	Environmental Management Agency
FAO	Food and Agriculture Organization
FCTZ	Farm Community Trust of Zimbabwe
GTZ	Germany Agency for Technical Cooperation (now GIZ)
IAD	Institute for Sustainable Agriculture, France
IAE	Institute of Agricultural Engineering
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IOM	International Organization for Migration
IRCS	International Red Crescent Society
MLARR	Ministry of Lands, Agriculture and Rural Resources
NEPAD	New Partnership for African Development
NGO	Non-governmental organization
SAT	Sustainable Agriculture Trust
SSA	Sub-Saharan Africa
ZCFU	Zimbabwe Commercial Farmers' Union
ZFU	Zimbabwe Farmers Union
Zimpro	Zimbabwe Project Trust

PART I

1. INTRODUCTION

2. SUSTAINABLE INTENSIFICATION OF AGRICULTURAL PRODUCTION AND ECOSYSTEM SERVICES

3. SUPPORTIVE POLICY CONDITIONS

CHAPTER 1
Introduction

1.1 THE FUTURE OF AGRICULTURAL SOILS AND ECOSYSTEM SERVICES

Global food demand is steadily growing, due to increasing world population (currently ~1.1 percent per year and decreasing towards zero), and changes of food habits due to urbanization and per capita economic growth. With current dominant production systems it is proving difficult to increase agricultural production sustainably to meet demand, and this in a sustainable way. Additional challenges are posed in some regions with a limited agricultural potential, due to climatic conditions

Continuous agricultural soil degradation and increasing water scarcity are threatening agricultural productivity (efficiency) and production (output). Major reasons for this development are intensification of production based on mechanical tillage and agrochemicals in the industrialised nations while using extractive production methods and overgrazing in the developing countries. Symptoms of soil degradation are soil erosion by water and wind, and loss of soil organic matter, structure, and soil compaction. In addition soil degradation increases the vulnerability to droughts, thus increasing their frequency. Precious rain water is lost by run-off instead of being infiltrated and stored in the soil and as ground water. Yield levels can be maintained only with ever increasing inputs, fertilizers and irrigation water causing in addition pollution problems. Higher production costs, caused inter alia by increasing prices for fuel and other inputs, cut farm incomes to an extent which threatens the survival of many farms. Further, with tillage agriculture

FIGURE 1
Soil tillage consumes high quantities of diesel oil, dries out the soil and provokes erosion by wind and water

and soil degradation, it is not possible to adequately harness the necessary ecosystem services for the society such as clean water, erosion control, carbon sequestration, nutrient cycling, etc.

The need, therefore, is for farmers to take up more sustainable, productive and profitable ways of production that do not damage the soil, landscape and environment, and can deliver both higher productivity and enhanced ecosystem services. However, the land management systems now applied are damaging soils and limiting their capacity to generate rising yields and other ecosystem services on a sustainable basis. At present, the almost world-wide standard practice is to plough before planting a crop in order to loosen the soil and create a weed free seed bed. Mineral fertilizers are applied to replace the soil nutrients taken up by crops. Most agencies that advise farmers on technology choices – and the firms supplying inputs – recommend that increased production should come from more frequent tillage, higher levels of fertilizer and pesticide applications and the use of seed of genetically engineered seeds. This type of farming since the end of WWII has enabled global food production to expand in line with fast rising demand but there is a growing recognition that it is degrading the soil and thus is not sustainable economically and environmentally.

Moreover, it has 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 and the yield increases obtained with more inputs are declining, eventually reaching zero or negative values as, for example, already observed in the home country of the green revolution, India.

The problem is that, in many situations the combination of increasingly frequent inversion and non-inversion tillage, a failure to supply nutrients at sufficiently high levels to prevent "mining", and low levels of biomass restitution to the soil results in a progressive degradation of soil health and structure and its fertility and with this of its productive capacity and ability to respond to production inputs. This in turn normally leads to decreased factor productivity, 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 soil biodiversity, especially when crop residues are not retained and soil biota is dysfunctional. The result is a breakdown of soil aggregates and a reduction in the pore spaces within soils that are vital for their drainage and aeration, and their functioning as effective media for plant growth and ecosystem services. Tillage also reduces numbers of soil fauna, most noticeably a reduction in earthworm numbers with their inherent capacity to aerate the soil, incorporate organic matter to lower soil depth and create a porous soil.

These tillage-induced processes lead to physical changes in soil structure with subsequent reduction in a soil's capacity to absorb and hold water, nutrient 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 resulting in downstream flooding and pollution. Loss of organic matter also reduces the soil chemical and biological processes, so important in providing the humic gums which contribute to the stability of soil aggregates and release nutrients for uptake by plants. 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 tillage-based farming methods with bare and exposed soils 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.

1.2 NEED FOR A CHANGE OF PRODUCTION SYSTEMS AND AGRICULTURAL POLICIES

The above described situation calls for a drastic change in agricultural production systems at the paradigm level. What is required are production systems which are no longer extractive and disruptive of ecosystem functions, i.e. which protect field from water run-off and soils from erosion, and which maintain soil fertility by restitution of organic matter and plant nutrients exported from the field.

The "key" to a sustainable future is to move towards environmentally friendly farming systems that are 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, 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.

Water use-efficiency, may it be rain water or irrigation water, has to be increased in many parts of the world. This is pertinent in face of increased probability of drought and dry spells during the cropping season due to climate change and increasing competition for water between the agricultural sector and other consumers. Shrinking net returns of farms due to increased input prices and reduced production because of progressing soil degradation threaten the survival of many farm households, if no measures for reducing production costs and degradation are taken. It is also questionable if governments can continue subsidising agricultural production to the same extent. Recent cuts of subsidies of fuel and fertilizers are signs of the continuous liberalisation of agricultural markets.

All of the above calls for on-farm changes but also for changes in agricultural and environmental policies.

Conclusion: There is an urgent need for a change to sustainable intensified crop production systems. Technical solutions are available, but supportive policies and institutional support are required for their adoption, especially by smallholder farmers.

CHAPTER 2

Sustainable Intensification of Agricultural Production and Ecosystem Services

Rising global food demand against the background of rising cost of energy and production inputs, land degradation and climate change calls for an increase in agricultural production. This is best achieved by intensification of production systems, but in a sustainable way, referred to by FAO as "Sustainable Intensification of Crop Production" (SCPI). SCPI has been defined as producing more from the same area of land while reducing negative environmental impacts and increasing contributions to natural capital and the flow of environmental services, also referred to as ecosystem services. For this farmers have to adopt what is generally called "Good agricultural practices". Good agricultural practices are environmentally friendly. They

Good Agricultural Practices

1. No Mechanical Soil Disturbance and Maintenance of Soil Cover with Residues:
   Soil is not tilled and all the necessary actions are carried out to achieve and maintain a proper soil surface residue cover for the production system. This minimizes soil erosion and degradation, and it promotes soil health and an efficient use of water and nutrients.
2. Crop Rotations/Associations/Sequences:
   It promotes the most diverse and intensified cropping system (involving rotations, sequences and associations) possible according to the economic and agro-ecological conditions (soil and climate).
3. Integrated Pest Management (IPM):
   Damaging and beneficial species are monitored to determine a management measure, if necessary, based on the economic damage threshold. Approved and registered phytosanitary products are used, and selective active principles, with minimum impact on environment and human health, are prioritized.
4. Efficient and Responsible Phytosanitary Products Use:
   It considers the conditions under which the products used are applied, stored, transported, etc., and the residues they may produce are properly disposed. The personnel are properly trained and have all the necessary safety equipment.
5. Balanced Nutrition:
   It promotes the proper use and the balanced replacement of soil nutrients, based on soil testing and plant analysis, and also nutrient cycling, whenever the system allows it, avoiding transfer, concentration and/or contamination due to excesses. It avoids soil degradation and aims to increase productivity.
6. Stockbreeding Information Management:
   It complies with the required sanitary documentation and other traceability evidences according to national regulations.

Adapted from: AAPRESID. http://www.ac.org.ar/

rely less on external inputs and more on biological processes and synergistic interactions between system components. Nutrient recycling and build up of soil organic matter are key processes. This is very much in line with ecosystems approaches to production, as **agricultural landscape is an altered and managed ecosystem, an agro-ecosystem**. Nutrient recycling and build up of soil organic matter are key processes. This is very much in line with ecosystems approaches, as **agricultural landscape is a managed ecosystem, an agro-ecosystem**.

2.1 ECOSYSTEM SERVICES

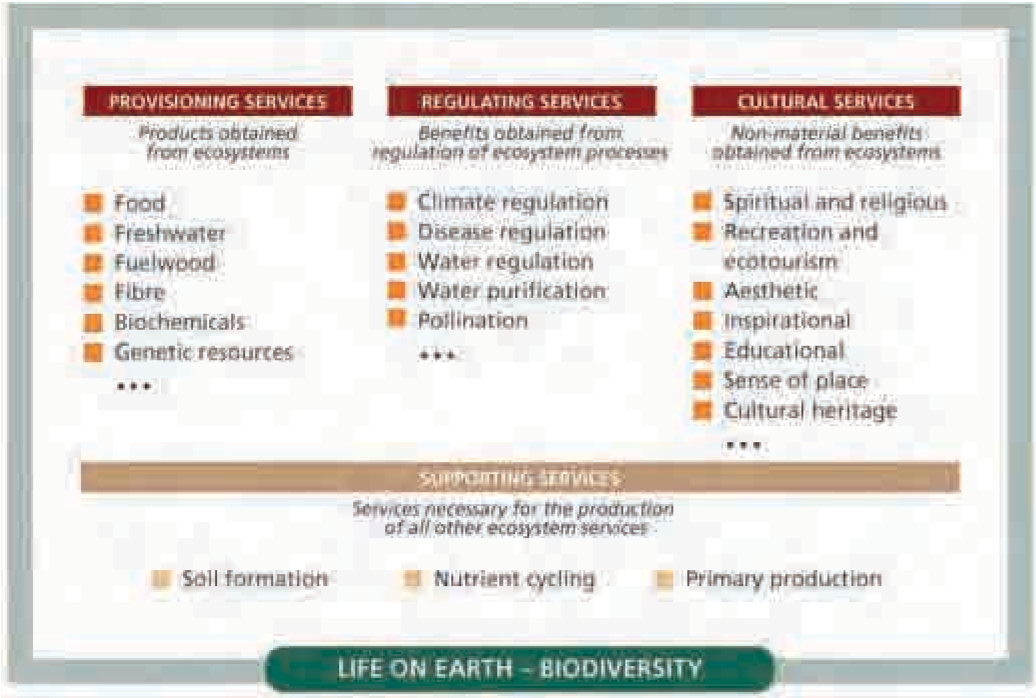
Societies everywhere benefit from the many resources and processes supplied by nature. Collectively these are known as ecosystem services, and include clean drinking water; edible and non-edible biological products; processes that decompose and transform organic matter; and regulatory processes that maintain air quality. Many of the key ecosystem services are considered to be important environmental services of a public goods nature. These ecosystem services operate at various levels from field scale to agro-ecological or watershed scale and beyond.

Ecosystems services can be classified in different categories (Table 1), such as:

- **Provisioning services** – food; water; pharmaceuticals, biochemicals, and industrial products; energy; genetic resources etc.;
- **Regulating services** – carbon sequestration and climate regulation; waste decomposition and detoxification; purification of water and air; crop pollination; pest and disease control; mitigation of floods and droughts, etc.;
- **Cultural services** – cultural, intellectual and spiritual inspiration, recreational experiences, scientific discovery, etc.
- **Supporting services** – soil formation; nutrient dispersal and cycling; seed dispersal; primary production, etc.;

Healthy ecosystems contribute directly or indirectly to human well-being. However most of them are currently in decline, and making their value clear to those who benefit from them, but are not direct land users, can encourage investment in their protection and enhancement.

TABLE 1
General Ecosystem Services



Source: http://www.fao.org/es/esa/pesal/aboutPES1.html

2.2 ECOSYSTEM APPROACH TO SUSTAINABLE INTENSIFICATION

To promote sustainable crop intensification and to protect ecosystem functions and services at the same time, an ecosystem approach has to be applied. The ecosystem approach uses inputs, such as land, water, seed and fertilizer, to complement the natural processes that support plant growth, including pollination, natural predation for pest control, and the action of soil biota that allows plants to access nutrients. The ecosystem approach can provide the "win-win" outcomes required to meet the dual challenges of feeding the world's population and saving the planet. SCPI will allow countries to plan, develop and manage agricultural production in a manner that addresses society's needs and aspirations, without jeopardizing the right of future generations to enjoy the full range of environmental goods and services. One example of a win-win situation – that benefits farmers as well as the environment – would be the elimination of mechanical soil tillage as a practice that is highly disruptive to soil life and structure, together with a reduction in the overuse of inputs such as mineral fertilizers and pesticides. Reduced spending on agricultural inputs can free resources for investment in farms and on farm families' food, health and education.

2.3 CORE ECOLOGICAL ELEMENTS OF SUSTAINABLE PRODUCTION SYSTEMS

The ecosystem approach needs to be applied throughout the input supply-production-output value chain in order in order to increase efficiencies and strengthen the global and local food and agricultural systems. At the scale of cropping systems, management should be based on biological processes and integration of a range of plant species, as well as avoidance of soil tillage, adopting integrated approaches to crop, nutrient, water and pest management, and the judicious use of external inputs such as fertilizers and pesticides. SCPI is based on agricultural production systems and management practices that are described in the following chapters. They include:

- maintaining healthy soil to enhance crop nutrition and ecosystem services;
- cultivating a wider range of species and varieties in associations, rotations and sequences;
- using well adapted cultivars and good quality seeds as well as appropriate sowing time, seedling age (in the case of rice), spacing and seed rate;
- integrated management of insect pests, diseases and weeds;
- efficient water management; and
- effective farm power and efficient energy use.

For optimal impact on productivity and sustainability, SCPI will need to be applicable to a wide variety of farming systems, and adaptable to specific agro-ecological and socio-economic contexts. It is recognized that appropriate management practices are critical to realizing the benefits of ecosystem services while reducing negative consequences and externalities from agricultural activities.

Farming systems for sustainable crop production intensification can offer a range of productivity, socio-economic and environmental benefits to producers and to society at large, including high and stable production and profitability; adaptation and reduced vulnerability to climate change; enhanced ecosystem functioning and services; and reductions in agriculture's greenhouse gas emissions and "carbon footprint".

These farming systems need to be based on three technical objectives:

- simultaneous achievement of increased agricultural productivity and enhancement of natural capital and ecosystem services;
- higher rates of efficiency in the use of key production inputs, including water, nutrients, pesticides, energy, land and labour;
- use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses.

The farming practices required to implement these objectives will differ according to local biophysical and socio-economic conditions and needs (FAO, 2011). However, in all cases and in all production systems they will need to:

- *minimize soil disturbance by avoiding mechanical tillage* in order to maintain soil organic matter, soil structure and overall soil health;
- *enhance and maintain a protective organic cover* on the soil surface, using cover crops and crop residues, in order to protect the soil surface, conserve water and nutrients, promote soil biological activity and contribute to building soil health and to integrated weed and pest management;
- *cultivate a wider range of plant species* – both annuals and perennials – in associations, sequences and rotations that can include trees, shrubs, pastures and crops, in order to enhance crop nutrition and improve system resilience as well contribute to integrated weed and pest management.

Those three key practices are generally associated with **Conservation Agriculture (CA),** which has been widely adopted in both developed and developing regions in all continents and agro-ecologies. However, in order to achieve the sustainable crop production intensification (SCPI) necessary for increased food production, they need to be supported by five additional management practices:

- *the use of well adapted varieties* with resistance to biotic and abiotic stresses and improved nutritional quality planted at an appropriate time, seedling age and spacing;
- *enhanced crop nutrition based on healthy soils*, through crop rotations and judicious use of organic and inorganic fertilizer;
- *integrated management of pests, diseases and weeds* using appropriate practices, biodiversity and selective, low risk pesticides when needed;
- *efficient water management*, by obtaining "more crops from fewer drops" while maintaining soil health and minimizing off-farm externalities;
- *careful management of machines and field traffic* to avoid soil compaction.

Ideally, SCPI is the combination of all of the above practices applied simultaneously in a timely and efficient manner. However, the very nature of sustainable production systems is dynamic: they should offer farmers many combinations of practices to choose from and adapt, according to their local production conditions and constraints.

A management consideration relevant to SCPI is the role of farm power and mechanization. In many countries, the lack of farm power is a major constraint to intensification of production. Using manual labour only, a farmer can grow enough food to feed, on average, three other people. With animal traction, the number doubles, and with a tractor increases to 50 or more. Appropriate mechanization can lead to improved energy efficiency in crop production, which enhances sustainability and productive capacity and reduces harmful effects on the environment (carbon emissions).

At the same time, uncertainty about the price and availability of energy in the future suggests the need for measures to reduce overall requirements for farm power and energy while maximizing energy use efficiency. Conservation

Agriculture can lower energy requirements by up to 60 percent or more, compared to conventional farming. The saving is due to the fact that most power intensive field operations, such as tillage, are eliminated, which eases labour and power bottlenecks particularly during land preparation. Investment in equipment, notably the number and size of tractors, is significantly reduced (although CA requires investment in new and appropriate farm implements such as direct seeders). The savings also apply to small-scale farmers using hand labour or animal traction. Studies in the United Republic of Tanzania indicate that in the fourth year of implementing zero-tillage maize with cover crops, labour requirements fell by more than half.

Source: FAO, 2011: Save and Grow. (*http://www.fao.org/ag/save-and-grow/index_en.html*)

2.4 THE ROLE OF MULTI-FUNCTIONAL AGRICULTURE

Agriculture is an altered and managed ecosystem, and to be ecologically sustainable, it must deliver specific ecosystem services to society in addition to food and other biological products.

Major agro-ecosystem services

- Climate change mitigation
  The role of agriculture in mitigating climate change consists of reducing its own emissions and enhancing the absorption or "sinks" of greenhouse gases (GHG). It is important to further unlock the agricultural sector's potential to mitigate, adapt and make a positive contribution through GHG emission reduction, production efficiency measures including improvements in energy efficiency, biomass and renewable energy production, carbon sequestration and protection of carbon in soils based on innovation.
- Watershed protection
  Agriculture accounts for more than half of all water use in the world and can contribute to pollution of water resources, thus influences both the quantity and quality of water available for other human uses. Changing agricultural practices could contribute to water quantity available by improving the productivity of the water it uses and by promoting the recharge of groundwater aquifers and it can contribute to improved water quality by reducing or avoiding the pollution of ground and surface waters originated from agricultural production.
- Biodiversity conservation
  Biodiversity is an environmental good and its conservation has assumed great importance in the effort to improve environmental management and ecosystem health. Agricultural producers can contribute to biodiversity conservation.

Farmers play an important role as ecosystem managers in that they balance their decisions regarding land and other agricultural inputs for production and modify their practices to adjust the positive and negative impacts to the environment. However, so far the main guiding principle is short term economic profit attributed mainly to the agricultural production. Yet, by their choices of production inputs and management practices, farmers shape their impacts on the environment. Despite their importance, the current economic system does not account for these functions and the result is that they essentially are not 'valued' in the market. Environment costs are just externalized.

Some agronomic practices, especially those in Conservation Agriculture (i.e. the practice of no tillage and direct seed drilling through mulch cover) are capable of providing ecosystem services such as the provisioning, regulating and cultural services. These ecosystem services all rely on the "supporting services" (Table 1), such as soil formation, nutrient and water cycles and the production of plant biomass. It is the farmer who manages, for better or for worse, the formation and preservation of soils, the nutrient cycle and the total production of plants by the yields. The objective is good management and intensive production but with more from less.

> Maximum biomass production increases the production of ecological services and benefits to the whole of society!

A natural order exists in biomass management:

1. Soil cover: The soil must be covered all year round for this cover to protect and nourish the biological activity. The farmer must recycle a significant part of crop residues into the soil to build and preserve it.
2. Carbon storage in the soil: The higher the yields are, the greater the amount of plant residues are that can remain on the ground, the greater the biological activity and the greater carbon storage.
3. Human food and animal feed: Production of food and animal feed is the prime objective of agriculture. And food safety is not secure in many parts of the world. Depending on the climate zone and food and feed requirements, it is always a debate which part (percentage) of the total yield has to be used for society, and which part of yields (biomass) remains on the ground to accommodate carbon sinks and biodiversity.
4. Biomaterials: plant fibres are more often used in the industry to replace synthetic materials (because of light weight) and also in house construction (heat insulation).
5. Renewable energy: A fact often forgotten is the high energy dependence of agriculture on fossil energies (fuel for field work and transport, fertilizers, pesticides). Food sovereignty relies on secure energy. The production of bioenergies secures food for society regardless of the energy crisis context.

> Biogas and biofuel production must supply the autonomy of agricultural production and distribution systems in priority - just in case.

Achieving high yields and permanent recycling is the cornerstone of sustainability. With good agronomic management techniques, achieving high yields is fundamental, to render all possible ecological services to society. Table 2 and Box 1 lists the contribution of sustainable crop production intensification (SCPI) practices, especially of Conservation Agriculture, to important ecosystem services and economic, social and environmental benefits.

Even though (good) farmers are increasingly expected to be ecosystem managers in addition to producing agriculture produce, they are not paid for the environmental services they provide to the society. If society realizes the value of these services, it should be willing to pay farmers for these services, including supporting the cost of transformation from tillage-based systems to no-till CA systems.

TABLE 2
Contribution of sustainable intensification farming system practices to important ecosystem services

Objective	System component			
	Minimized soil disturbance/ no tillage	Soil cover	Legumes to supply plant nutrients	Crop rotation
Simulate optimum "forest-floor" conditions	*	*		
Reduce evaporative loss of moisture from soil surface		*		
Reduce evaporative loss from upper soil layers	*	*		
Minimize oxidation of soil organic matter and loss of CO_2	*			
Minimize soil compaction	*	*		
Minimize temperature fluctuations at soil surface	*	*		
Provide regular supply of organic matter as substrate for soil organism activity	*	*		
Increase, maintain nitrogen levels in root zone	*	*	*	*
Increase cation exchange capacity of root zone	*	*	*	*
Maximize rain infiltration, minimize runoff	*	*		
Minimize soil loss in runoff and wind	*	*		
Permit, maintain natural layering of soil horizons through action of soil biota	*	*		
Minimize weeds	*	*		*
Increase rate of biomass production	*	*	*	*
Speed recuperation of soil porosity by soil biota	*	*	*	*
Reduce labour input	*			
Reduce fuel/energy inputs	*		*	*
Recycle nutrients	*	*	*	*
Reduce pest-pressure of pathogens				*
Rebuild damaged soil conditions and dynamics	*	*	*	*
Pollination services	*	*	*	*

Source: FAO, 2011: Save and Grow. (http://www.fao.org/ag/save-and-grow/index_en.html)

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.

CHAPTER 3

Supportive policy conditions

Most governments support agriculture financially, i.e. subsidised food production. Major objective is to enhance production in order to cover food requirements. Depending on the importance of agriculture within the national economy and the political influence of farmer organisations agriculture is subsidised even beyond national food requirements, i.e. surpluses are produced and food exports subsidies are paid. National spending for subsidies to the agricultural sector can be substantial. In some cases governments subsidise means of production such as seeds, fertilizers, pesticides, and fuel. Often guaranteed prices for products are paid which are above world market prices or import taxes for agricultural machinery are reduced. These subsidies are generally paid unconditionally, i.e. independent of production methods and impacts on the environment. In many cases subsidies generate negative effects, overdoses of fertilizers and pesticides pollute ground and surface waters, guaranteed prices for certain commodities lead to monocultures with all kinds of negative impacts on soil health and agro-biodiversity.

A sustainable intensification of crop production based on an ecosystem approach calls for a change of government policies and a reorientation of subsidies or incentives. In line with this it should no longer be possible to externalize environmental costs. These costs have to be internalized. In many countries, especially industrialized countries, the importance of the agricultural sector is declining and it becomes more and more difficult for governments to justify subsidies to this sector. A reorientation of subsidies towards protection of the environment is easier to justify. Farmers in the future will not be just recipients of subsidies but will be paid for protecting the environment while producing food and other agricultural products.

> Future agricultural policies should follow the principle:
> Public funds for publicly wanted services

3.1 AGRICULTURAL POLICY REFORM FOR ENVIRONMENTAL MANAGEMENT

The benefits of government financing of agriculture will become more visible to society and will have a more remarkable surplus value to society if they are linked, in addition to the goal of affordable food, to publicly wanted services in the field of environment, nature, animal and climate protection and if they contribute to preserving employment in and developing rural areas. Therefore supportive agricultural policies should also be based on incentives for environmental management. Paying for Environmental Services (PES) from public funds is one of such mechanisms. (Source: *http://www.fao.org/es/esa/pesal/aboutPES4.html*)

The policy challenge is to develop incentives for farmers to produce ecosystem services while meeting the demand for food. Important policy questions are:

- What are the incentives that will make the farmers provide ecosystem services?
- Are farmers willing to change their land management practices in exchange for a payment, and if so, how much?
- Which farmers are willing to change their practices and should future policies be targeted toward specific groups of farmers?
  (*Source: Christina B. Jolejole, Scott M. Swinton and Frank Lupi*).

Progress in agricultural policy reform

- Policies gradually moving away from commodity specific support measures – decoupling
- Farmers have more production flexibility while still being eligible for support
- Increasing impact of environmental, food safety and animal welfare regulations – and cross compliance
- Policy reform offers the potential for better targeting – including for environmental services
  (*Source:* OECD, 2007. Wilfrid Legg)

Empirical studies with Conservation Agriculture have found that the most important motives for adoption of conservation practices are "selfish", financial-economic concerns showed that the best way to increase the use of conservation practices is to make them profitable. However non-financial factors also play a role in conservation related decisions because producers may gain direct personal satisfaction from the improved environmental quality.

Why do we need an agricultural policy reform?

Changes of agricultural policies are necessary in order to respond to the new challenges notably to:

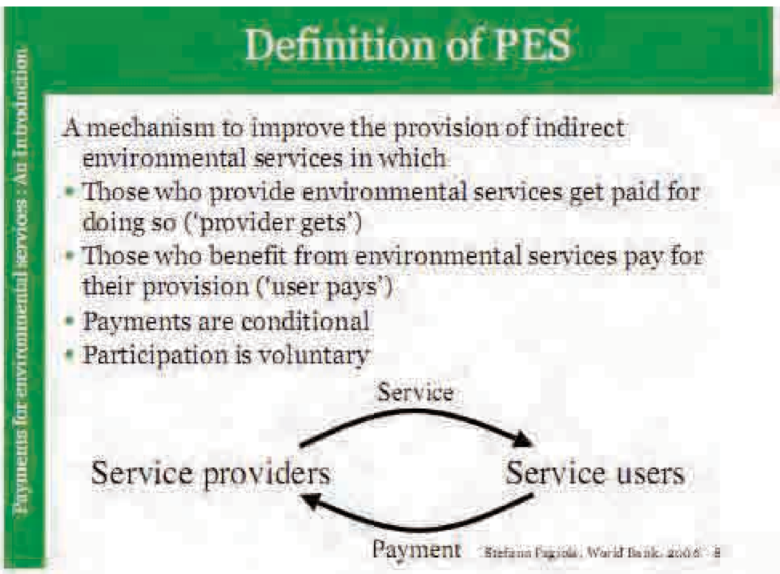
- address rising concerns regarding national and global food security
- enhance the sustainable management of natural resources such as water, air, biodiversity and soil,
- deal with both the increasing pressure on agricultural production conditions caused by ongoing climatic changes, as well as the need for farmers to reduce their contribution to GHG emissions, play an active role in mitigation and provide renewable energy.

3.2 PAYMENT FOR ECOSYSTEM SERVICE (PES)

The concept of Payments for Ecosystem Services (PES) - also referred to as Payments for Environmental Services - seeks to create positive economic incentives to change human behaviour in ways that increase or maintain environmental services such as watershed protection, the sequestration of carbon and the provision of habitat for endangered species.

The basic principle behind PES is that resources users and communities that are in a position to provide environmental services should be compensated for the costs of their provision, and that those who benefit from these services should pay for them, thereby internalizing these benefits (Figure 2).

FIGURE 2
Definition of PES



Source: Stefano Pagiola, Environment Department, World Bank, 2006 (http://siteresources.worldbank.org/INTEEI/Resources/IntroToPES.pdf)

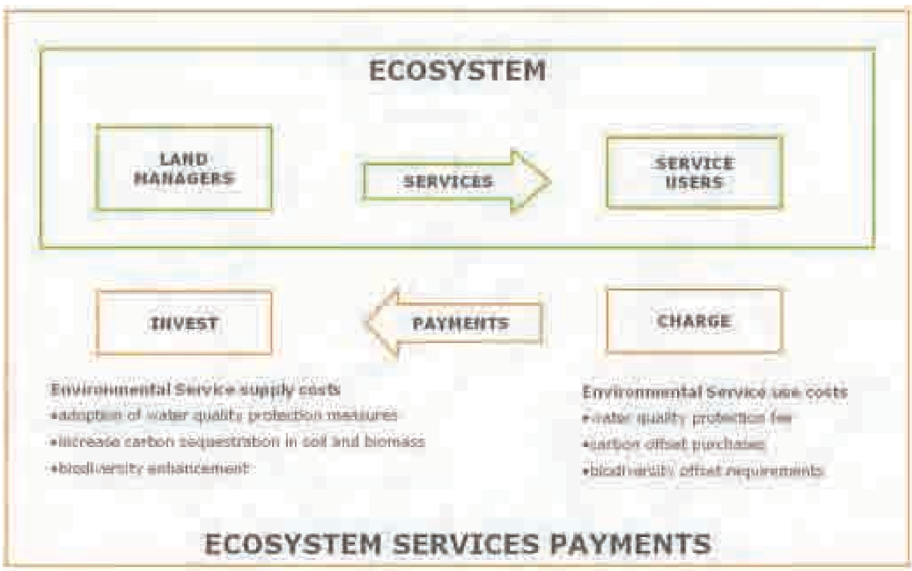
But which techniques ensure efficient agricultural production and the supply of ecological services to society? How can a farmer alter his/her practices and techniques to produce a maximum of services and public goods?

PES schemes seek to attribute a certain societal value to environmental services and establish appropriate pricing, institutional and redistribution systems that can lead to sustainable and socially optimal land use practices. These schemes tend to work best when the value of environmental services is high for beneficiaries and the cost of providing the services is low.

There are different types of Payments for Environmental Services schemes. Most PES schemes are voluntary arrangements between service providers (communities or land user organisations or individual land users) and private companies, such as water supply companies. In such cases the buyer of services profits directly from the arrangement.

With government-financed schemes the link between service provider and beneficiary is not as clear. In these cases, the government pays land managers, on behalf of civil society (=service beneficiaries), to adopt improved land management options and thus address a particular environmental problem (Figure 3).

FIGURE 3
Operation of PES schemes: a simplified representation



Government funded PES in general aims at:
- Improving water, soil and air quality
- Preserving agricultural landscapes (cultural)

- Preserving biodiversity and wildlife habitats
- Reducing greenhouse gas emissions
- Sequestering soil carbon
- Ensuring viable farms to contribute to countryside stewardship in rural communities.

The emphasis changes with the prevailing nature of ecosystems and the pressure applied on it by agriculture, particularly tillage agriculture. To be efficient, PES requires environmental protection legislation and a well functioning agricultural administration. Farmers need to be informed and instructed on the procedures and farming practices and their impact on the environment need to be closely monitored.

How can the poor profit from PES?

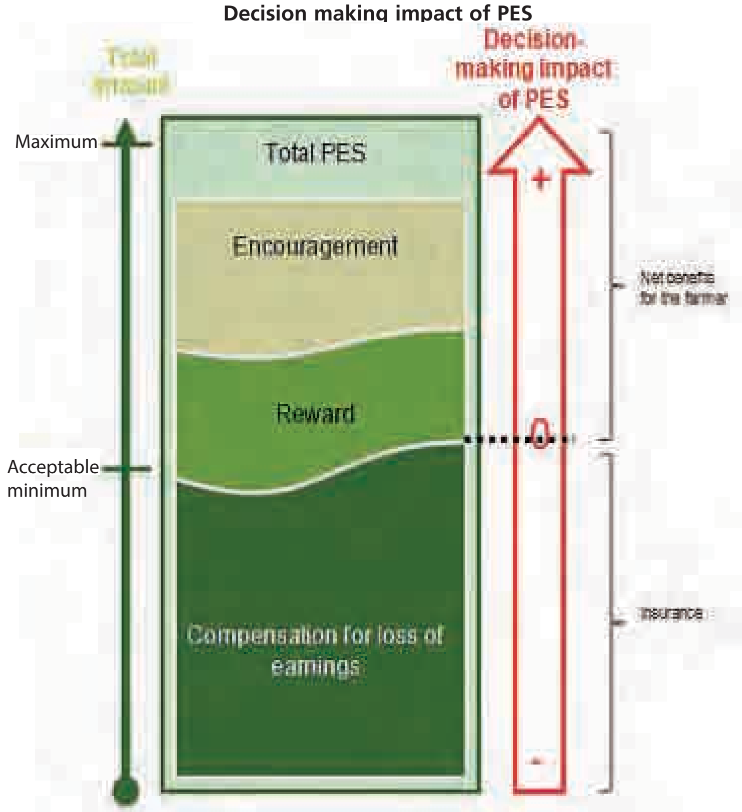
Poverty is a major cause of environmental degradation. As, e.g. in Africa, by far the greatest part of the agricultural land is managed by smallholders, including them in a PES programme is a challenge. It would result in both environmental benefits and poverty reduction. PES schemes must be designed especially for smallholders, to make them attractive. This means, the incentive to change the production system must be great enough. Besides covering the costs of a change, including the risk of potential losses, farmers must be rewarded for their engagement (Figure 4). The proportional reward must be higher for a small farm compared to a great estate, but the reward could also be delivered indirectly through improved extension services, financing assistance for CA equipment purchases and quality seeds or information and training etc. which could accompany as supportive measures PES programmes. There is the need to understand how PES programmes can be designed to maximize poverty reduction and minimize possible negative effects, whilst not undermining the achievement of the programmes' environmental goals.

(*Source:* http://www.fao.org/es/esa/pesal/aboutPES8.html)

3.3 EXAMPLES OF PES SCHEMES

CA-based ecosystem services operate in different parts of the world. Controlling land degradation, particularly soil erosion, caused by tillage, exposed soils and depletions of soil organic matter, has been a main objective of most of such initiatives. Examples are: the agricultural carbon offset scheme in Alberta, Canada; the watershed services from Paraná III Basin in Brazil; the control of soil erosion in Spain; the control of water erosion and reduction in dust storms, and combating desertification and drought in the loess plateau of the Yangtze and the Yellow River basin in China; reducing susceptibility to land degradation in western Australia, the Conservation Reserve Programme in the United States that pays farmers for their protection of endangered wildlife habitat, open space and/or wetlands and the plans for a new EU Common Agricultural Policy.

FIGURE 4
Decision making impact of PES



Source: Agriculture 2050 starts now and here. IAD, 2011 (according to FAO data, 2007)

The initiatives in Canada, Brazil and the EU are elaborated below.

Canada: Carbon Offset Trading Scheme in Alberta

The province of Alberta has operated a greenhouse gas offset system since 2007 that allows regulated companies to offset their emissions by purchasing verified tonnes from a range of approved sources including agriculture projects. Over the last two years the amount of offsets used by companies for compliance has been steady at about 36 percent of the total annual accounts. Agricultural offsets have contributed about 40 percent of all offsets. The most popular protocol has been the Tillage System protocol which acknowledges the soil carbon sequestration through implementation of No-Till practises. The Tillage System protocol has contributed over 5 million tonnes of offsets worth about C$60 million over the last four years of the offset system. Farmers have developed improved production and record systems. Very often the financial benefits to the farmer by adopting a protocol far exceed any offset payment for the greenhouse gas savings portion.

Brazil: Watershed Services in the Paraná Basin

As part of a strategy for improvement, conservation and sustainable use of natural resources, the Itaipú Dam *Programa Cultivando Água Boa* (cultivating good water), has established a partnership with farmers to achieve their goals in the Paraná III Basin located in the western part of Paraná State on the Paraguay's border. The dam´s reservoir depends on the sustainable use of soil and water in the watershed for efficient electricity generation. Sediments and nutrients entering the reservoir resulting from inappropriate land use pollute the water used by the turbines to generate electricity. This phenomenon shortens the reservoir life´s and increases the maintenance costs of power generating turbines increasing therewith electricity generation costs. Thus, in principle, payments could be made through a programme to improve the conditions of electricity generation. The spatial unit in this programme is the watershed. Functioning as a community joining many farmers in the watershed, they reach a scale where environmental impact can be monitored with suitable indicators to establish a system for payment for environmental services.

One of the partnerships built in the *Cultivando Água Boa* programme developed through an agreement with the Brazilian no-till federation (FEBRAPDP) is the Participatory Methodology for Conservation Agriculture Quality Assessment. Through this programme, at first, the partners plan to measure impacts of farm management through a scoring system indicating how much each farm is contributing to improving the water conditions. Considering the polluter/payer and provider/receiver principles set in the Brazilian Water Resources Policy, farmers with good scores will be paid for their proactive action to deliver watershed services once the Paraná Watershed Plan is established. This will be a new framework for services provided by farmers as compensation for their proactive approach to improve the reservoir water quality and reduce costs for electricity generation by the Itaipú Dam.

Source: *Kassam et al. 2011: Harnessing Ecosystem Services with Conservation Agriculture in Canada and Brazil. 5th World Congress of Conservation Agriculture incorporating 3rd Farming Systems Design Conference, September 2011 Brisbane, Australia (www.wcca2011.org).*

European Union - Payment for Ecological Services (PES) under the new Common Agricultural Policy (CAP) from 2013 onwards.

The actual Common Agricultural Policy (CAP) of the European Union (EU) aims at maintaining agricultural lands in a good agricultural and ecological state. However, the range of direct payments and the cross-compliance mechanism are complicated and did not reach the objective. In 2013 a new policy will become effective. The European Parliament proposal for the CAP reform encourages widely the adoption of cropping practices combining "minimum tillage techniques that provide cover crops and allowing catch crops and crop rotation" with a view to maximising photosynthesis and enriching the soil with organic matter. Other practices such as reducing greenhouse gas emissions by integrating renewable energies are also highlighted. Under the 2013 CAP reform, the European Parliament proposes to encourage farmers to commit to these techniques by incorporating special payment conditions financed by the European Union budget.

Under debate is a policy that reconciles agricultural production and environment protection. A new "Agriculture and Environment" policy should respond to the need for:

1. Adaptation to climate change
2. Protection of resources,
3. Economic business competitiveness,
4. Production in quantity and quality,
5. Reliable provisioning at affordable prices,
6. Production of energy and biodegradable materials, etc.

Agriculture has to produce environmental (ecological) services at the same time as it produces food. Some parties suggest promoting the orientation of agricultural practices by remunerating "ecological services".

Carbon or better carbon sequestration takes a central role in the debate. Ecological services should focus on a long-term "agricultural carbon sink" (biomass and soil organic matter). Such a policy could be fed by "Carbon Credits" (or carbon compensation mechanisms) and by Payment for Ecological Services (PES) under the new CAP from 2014 onwards. Farmers should be encouraged to alter their practices and reconcile production and protection. Farmers should imitate natural ecosystems and sequester maximum amounts of carbon to maximise plant production while producing at the same time fertile soils, clean water, strong biodiversity, quality food, biomaterials (wood, cotton, flax, hemp, etc.), energy (biogas, wood, ethanol, etc.), and sound landscapes.

Thus, the new CAP must act at two levels if the farmers are to provide consumer goods and ecological services to their fellow citizens:

- The first level involves creating a carbon sink. The political tools, via carbon credits, must allow farmers to put together carbon sequestration strategies in the soil and the plant biomass.
- The second level follows on from the agricultural carbon sink. The good biological and structural state of soils encourages the development of a powerful biodiversity capable of producing ecological services for society.

Certain techniques adopted in agriculture are perfectly capable of improving the "ecological" situation of lands. It has now been proven that Conservation Agriculture (no soil tillage) can increase carbon sequestration in soils, on one condition that the production and recycling of harvest residues are maximised for permanent soil cover and a suitable crop rotation is observed. The carbon storage in the soils is much higher the greater the crop yields and residue recycling in the soils, that the provision of organic matter can offset the outgoings. Using Conservation Agriculture practices (no till direct drilling through a cover crops and residue mulch) produces an agricultural carbon sink and, by extension, as in nature itself, all the ecological services linked to the development of biodiversity.

A dozen indicators identified by IAD can measure the efficiency of the agricultural carbon sink. The indicators are grouped into seven relevant themes, some of which need to be still improved by science.

1. Economic viability
2. Social viability
3. Efficiency of input use
4. Greenhouse gas
5. Soil quality
6. Water quality
7. Biodiversity

The use of the indicators aims at measuring farming practices and at detecting the strengths and weaknesses, thereby revitalising farmers' thinking and encouraging them to produce ecological services. Out of the indicators identified by IAD to measure ecological services, thirteen can be used directly:

1. Plant protection rate (IFT)
2. Nitrogen level
3. Energy balance
4. Renewable energy production
5. Irrigation water consumption
6. Greenhouse gas (GHG) rate
7. Yield per hectare
8. Soil cultivation intensity
9. Soil cover
10. Organic matter level
11. Soil utilisation
12. Biodiversity surface area

Monitoring the efficiency of farming practices to promote ecological services can be measured annually. The indicators IAD has identified are capable of this. Measuring results could easily be included in accounting records making them operational for regular monitoring of enterprises. The link between the accounts and the ecological service indicators would be an excellent statistical basis for the agricultural policy, thereby avoiding double or triple entry problems and establishing an excellent results control tool for the Civil Service. A PES strategy like this can easily be included in the future

CAP (2014) with the best cost-service-registration-control ratio via a simple declaration based on a copy of results measured.

Source: *Agriculture 2050 starts here and now. IAD, Paris, 2011. http://www.institut-agriculture-durable.fr/images/fichier/79_L-agriculture-de-2050-commence-maintenant-FRANCAIS.pdf*

3.4 OTHER GOVERNMENTAL STRATEGIES FOR ENHANCED DISSEMINATION OF INTENSIFIED SUSTAINABLE PRODUCTION SYSTEMS, NOTABLY OF CA

Farmers are just one stakeholder of the agricultural sector. Besides PES or direct payments to farmers, further support measures are required for a sustainable intensification of crop production. Such support could be understood as indirect PES and would be particularly useful for small scale farmers.

Conducive policies entail amongst others:

- credit lines for purchase of direct planters
- encouragement of farmers to form CA producer associations (common use of CA implements, mutual learning)
- support of agricultural service providers
- support of adaptive research and extension
- teaching of CA principles at agricultural schools and at universities (uptake into the curriculum)
- facilitation of exchange of information and experience within the country and neighbouring countries.

Credit lines

The lack of direct drills constitutes a major constraint for the adoption of CA practices. No-till direct seed-drills are not only much more expensive as conventional drills, but they are also not yet offered by suppliers of agricultural equipment in many countries. Suppliers hesitate to offer direct drills, as the demand is still limited. Thus farmers willing to buy a direct drill have to import it directly from foreign manufacturers in countries more advanced in CA. Only large farmers are in the positions to do this. Smaller farms cannot bear the costs of such drills, and are anyway hardly ready to invest in agricultural equipment. Thus government support is required in order to facilitate access to direct drills. The government could reduce import taxes and open a credit line (low interest) for the purchase of direct drills, or, as in some countries, offer direct subsidies for the purchase of no-till seed drills. This has proved to be quite successful in several countries.

Formation of Producer Associations

In many developing countries small farms dominate. Direct drills are too expensive for these farms. An option would be the formation of a producer organisation and the purchase of a no-till direct drill by the associations, for common use by the members. Producers associations would also facilitate exchange of experience amongst members. Extension agents could address themselves a group of farmers instead giving advice to individuals. Facilitation of the formation of producer organisation would support the dissemination of CA amongst smaller farmers.

Support of Agricultural Service Providers

The widespread adoption of CA practices is facilitated by agricultural services providers, who dispose of direct drills and sow crops on order. Tractor operators who already offer ploughing and harvesting services should be encouraged to also offer direct drilling services. This would ease the constraint to adoption of CA practices especially by smaller farms. The extension service should provide information on different types of direct drills and manufacturers to farm service suppliers, and the government should subsidise importation, either through reduced taxes or credits at favourable conditions. In addition service suppliers need training in the good use of the drills. Proper maintenance and calibration of herbicide sprayers is another issue where service suppliers need practical advice, training and supervision. Herbicides can be only effective when sprayers are in proper condition, including the correct choice of nozzles.

Apart from machinery, service providers should also offer seeds of drought tolerant cover crops and forage plants. Seed companies should import these seeds and multiply them locally, with a view of providing farmers with required seeds.

Support of Adaptive Research

While the site-specific application of Conservation Agriculture practices is the task of individual farmers and requires trying and observation, there are still some research questions requiring accompanying research. More information is needed, concerning e.g. crop rotations, weed control, increase of water use-efficiency, CA for fruit trees including olives, and possible solutions to the issue of crop/livestock integration, i.e. alternative forage sources (drought resistant forage crops). Producing vegetables with CA practices is another issue of special importance for regions where vegetables including potatoes are produced as summer crop under irrigation. The national research institutions, should install multi-station trials accompanied by on-farm trials in order to find answers to the most urgent questions.

Strengthening Agricultural Extension

Large-scale promotion of CA requires coordinated efforts of the extension service. Extension officers have to provide information and advice to farmers and encourage farmers towards changing their production systems. Extension services need to be equipped for this task. Specific training of extension officers is required. National and international research institutions like the institutes of the CGIAR system, should offer training courses for extension officers and farmers. The production of training manuals and videos could facilitate this task as well as the production of technical information leaflets for farmers. The organisation of field days is an excellent means of facilitating not only exchange amongst farmers but also providing feed back to extension and research staff.

Education

Students at agricultural schools and universities have to become acquainted with CA already during their studies. This requires the integration of CA in the curricula. Students should in addition undergo practical training in CA during their studies and whenever possible choose for their thesis a theme related to CA. Precondition for this reorientation is the provision of information to lecturers and university professors. Examples from other countries show that it is worthwhile to let students of primary and secondary schools get familiar with CA.

National and Regional Networking

Exchange of information and experience between practitioners and researchers at the national and regional level is a powerful tool for the promotion of CA. Experience with national and regional networks in Africa, North America and Latin America and Asia prove that these networks have helped to enhance the dissemination of CA practices. Networking is done mainly though e-mail and internet, but also through workshops, field days and farm visits. Networks can produce information bulletins and offer electronic discussion platforms, which allow individuals to ask amongst network members for specific information and experiences. Successful networks require a permanent secretariat and a coordinator. This in turn requires financial support either from the government or development cooperation organisations, at least in the first years. At the global level a CA-Community of Practice (CA-CoP) has been established as a virtual network, hosted by FAO (www.fao.org/ag/ca). At the national level, to start with, exchange visits by farmers and extension officers could be organised between neighbouring countries.

Regulation of water withdrawals for irrigation

The need for water to grow more food is increasing daily. The rapid urbanisation and change of food habits, more meat, vegetables and fruits, further increase water demand for food production. Farmers respond with expanding irrigation and pumping more water either from rivers, dams or from the ground. Lack of policies and laws or poor the implementation of existing laws and regulations lead to overexploitation of water resources.

Rivers and lakes shrink, the water quality is going down and groundwater tables are sinking at an alarming rate in certain locations. Governments have to undertake efforts to increase water productivity i.e. to promote agricultural practices that produce "more crop per drop" as well as facilitating the recharge of the aquifers. This entails regulation and effective control of water withdrawals and taxation of water consumption. In addition soils policies need to be enforced that prohibit agricultural practices causing water run-off and soil erosion. All this will force farmers to change their production systems and open the door for practices that increase water productivity, like CA practices.

Carbon credit trading

Through greater adoption of CA systems, there is enormous potential to sequester soil organic carbon, which would:

(1) help mitigate greenhouse gas emissions contributing to global warming; and
(2) increase soil productivity and avoid further environmental damage from the unsustainable use of tillage based systems, which threaten water quality, reduce soil biodiversity, and erode soil around the world.

Agricultural activities around the world contribute about 15 percent to the annual emissions of these greenhouse gases. Research during the past few decades has demonstrated the significant contribution that CA systems can have on reducing emission of greenhouse gases, as well as sequestering carbon in soil in form of organic matter.

Increase in the use of conservation practices by agriculture will help to assure the positive balance between carbon inputs and carbon outputs. Sequestration of soil organic carbon by farmers can provide an environmental commodity that benefits all of society through the mitigation of greenhouse gases. Early markets have shown that carbon offsets from conservation agriculture can be quantified, verified and traded. Carbon credit trading will provide an economic opportunity for farmers to adopt these ecologically based approaches to farming.

PART II

4. OPERATIONAL GUIDELINES

CHAPTER 4
Operational guidelines

4.1 PRACTICING SUSTAINABLE INTENSIFICATION OF CROP PRODUCTION AND ENHANCING ECOSYSTEM SERVICES

Farming systems for sustainable crop production intensification can be built on the three core technical objectives:

- simultaneous achievement of increased agricultural productivity and enhancement of natural capital and ecosystem services;
- higher rates of efficiency in the use of key inputs, including water, nutrients, pesticides, energy, land and labour;
- use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses.

Central element of sustainable crop production is appropriate soil management, as soil is the basis of plant production and the key production factor in crop and livestock farming, and forestry. Appropriate soil management, as practiced with CA, maintains soil health, and minimizes losses of soil, soil organic matter, and plant nutrients. Amongst the recommended principles listed below, practices related to soil management (minimum soil disturbance and permanent organic soil cover) are at the very top.

The above three objectives will need to be implemented using eight recommended management objectives:

- Minimum soil disturbance;
  Direct seeding (low disturbance)
  No-tillage (permanent)
  Prevention of soil compaction/controlled traffic
- Permanent organic soil cover
  Crop residues management
  Cover crops; relay crops; under-sowing (intercrops)
- Species diversification;
  Crop rotation, sequences, associations
  Fodder crops/pasture rotations, agroforestry
  Integration of legumes in the rotation
- Selection of suitable cultivar, planting time, age and spacing
  Cultivars with good production potential
  Cultivars with good rooting abilities

Good quality seed material
Planting at appropriate time, seedling age (in case of transplanting), seed rates and spacing

- Balanced plant nutrition;
  Increasing soil organic matter
  Balanced nutrient supply in adequate rates, including liming
  Placement of fertilizer where adequate (e.g. CULTAN, urea placement)
- Integrated pest management; including integrated weed management
- Efficient water management
  In situ rain water harvesting through enhanced infiltration - *see SG factsheet 4*
  Avoidance of unproductive water evaporation (mulch, no-till, cover crops)
  Control of irrigation according to plant requirements
  No flood irrigation, maintenance of aerobic soil compaction
- Careful management of machines and field traffic to avoid soil compaction.

Implementing these technical principles and recommended practices is what is generally called "good agricultural practices". Good agricultural practices are very much in line with CA and IPM. The following guidelines address themselves to farmers but may be used, too, by governmental organizations as a list of qualified criteria if any subsidies are assigned to farmers; and they may be integrated into sustainable agriculture certification systems focusing on CA. The guidelines aim at reorienting farming systems: reducing the dependence on soil tillage and on agro-chemicals (herbicides, pesticides, and synthetic fertilizers), and instead making better use of biological processes and synergies between system components.

4.1.1 Minimal or no mechanical soil disturbance

Soil tillage aerates the soil thus speeding up soil organic matter (SOM) decomposition. This results in significant reduction of SOM contents over time. In CA systems on the contrary SOM is build up as fields are not ploughed or tilled with other implements, but crops are sown directly into the undisturbed soil by using a special direct seeder. Soil disturbance is reduced to the opening of planting lines for seed placement (in manual systems: planting basins (holes). Effects of no soil disturbance are 1) reduced sheet, rill and wind erosion, 2) improved soil structure, 3) increased soil organic matter content, 3) increased plant-available moisture, 4) reduced CO_2 emissions from the soil. To increase the soil organic matter content no-tillage has to be combined with other elements of CA, i.e., a diverse crop rotation, and the right amount of N and a good Ca supply (especially in acid soils).

There exist different types of direct drills, equipped with disc, tine or cross-slot furrow openers. Soil disturbance differs between types; it is highest with tine openers and lowest with cross-slot openers. After seed placement the furrows are closed and pressed with special press wheels. The right choice of furrow openers depends on mainly soil type, quantity of crop residues and draught power. Tine openers are better suited for hard setting soils and little crop residues, while disc openers are more appropriate for softer soils and higher quantities of crop residues. Most direct seeders allow for simultaneous fertilizer application, below or besides seed rows.

Manual CA practices, recommended to smallholder farmers like planting pits or basins, *zaï* or *tassa,* are in fact ancient techniques used for regenerating degraded soils. The pits serve primarily for rainwater harvesting. But as available manure or compost is concentrated in the pits, biomass production is enhanced and by the time soil fertility restored – provided the planting stations remain undisturbed over time.

Many farmers fear that no-tillage favours soil compaction, with all its negative effects. Best means of avoiding soil compaction in mechanised farming is controlled traffic. Controlled traffic means using marked traffic lanes for all operations, thus limiting compaction to small distinct zones. For controlled traffic all implements (seeders, sprayers, fertilizer spreaders) need to have a particular width and wheel tracks are confined to specific traffic lanes. In addition field operations should be executed preferably when soils are dry.

4.1.2 Maintenance of permanent organic soil cover

Another basic principle of CA is that the soil must be always kept covered, either by the crop, crop residues, or cover crops. The soil cover protects the soil like a hat from the impact of sun, wind and rain. Soil erosion by water and wind is reduced if not prevented, water infiltration and retention is improved, loss of soil moisture by evaporation is reduced, weed germination and growth is suppressed, soils are protected from overheating and day temperature differences are reduced. Besides, soil cover provides constant food supply and habitats for soil micro and macro sauna which contributes greatly to biological tillage and humus formation. The quantity or percentage of soil cover depends on the crop rotation, biomass production (as a function of climate zone and soil type), alternative usage of crop residues (forage for livestock, sales, usage as construction material or fuel). Farmers should plan their crop rotations and livestock management as to enable always an efficient soil cover. In mixed farming systems forage crops (best legumes such as vetch, or legume/cereals or grass mixtures) should be produced in order to reduce the need of using crop residues for livestock feed.

4.1.3 Species diversification - Crop rotation/associations/sequences

Crop rotation forms one of the three pillars of CA. Rotations should ideally be longer than 3 years. The longer and diverse the cycle the better the effect on soils, weed and pest control as well as on crop yields. Length of cycle and choice of crops depends on soil, climate (length of season, rainfall), and market situations. While in moderate climates more different crops can be grown, in dry or cold climates the choice is rather limited, often only short cycle cereals and some legumes can be grown. In sub-humid climates rotations can be enriched by planting short cycle crops or green manure-cover crops after harvest of the main crop or as inter-/relay crop. Where possible, the integration of livestock through pasture or forage crops into a crop rotation can widen the options for economic rotational crops.

Crop rotation helps to avoid the build up of pathogens and pests as well as specific weeds that often occur when one species is continuously cropped. Integrating legumes, grain legumes or green manures, enriches the soil with (atmospheric) nitrogen, thus allowing savings of nitrogenous fertilizers. Different crops have different nutrient requirements, thus avoiding deficiencies of certain (trace) elements. By alternating deep-rooted and shallow-rooted plants different soil layers are exploited. Deep rooting plants can make use of nutrients leached under shallow rooting crops. In mixed farming systems crop rotations should be enriched by forage crops (legumes or cereals/legumes mixtures).

Crop rotations/associations/sequences should include leguminous crops to profit from biological nitrogen fixation. This is an efficient and low-cost measure of enriching N-poor soils, e.g. in African savannas. The use of leguminous crops and trees that are able to fix atmospheric nitrogen, in combination with applications of mineral P-fertilizers, has shown very promising results. Depending on crops and environment substantial amounts of nitrogen (>100 kg/ha) can be fixed and made available for subsequent crops. The combination of mineral fertilizer application and dual-purpose grain legume, such as soybean, intercropped or relay-cropped with maize, can more than double yields of maize in the following season.

4.1.4 Selection of suitable cultivars, planting time, age, seed rate and spacing

Sustainable intensification requires the use of good, high quality (certified) seeds, guarantying high germination and emergence rates, as well as vigorous and healthy crops. Crop cultivars should be suited to different agronomic practices, and respond to farmers' needs in locally diverse agro-ecosystems and to the effects of climate change. Important traits will include greater tolerance to heat, drought and frost, increased input-use efficiency, and enhanced pest and disease resistance. So-called modern high-yielding varieties are not always the best choice; local cultivars, including traditional varieties, are often better adapted to local environmental and socio-economic circumstances, and offer reasonably high yields and profit under Conservation Agriculture system. The aim should not be just high yields but high yield stability, which is producing enough food for the family even in extreme (dry) years. Producing own seeds helps to reduce costs, but it requires a careful selection and cleaning of seeds, as well as seed treatment and storage. Standard seed rates recommended by national extension services are in general too high, and do not take into account of the fact that with Conservation Agriculture, there is much less seed loss. Also, extension services often do not take into account of situation of individual farms in terms of the variation in biophysical conditions within the fields and between fields.

Sustainable intensification of crop production requires a redefinition of breeding objectives and practices. It will involve the development of a larger number of varieties drawn from a greater diversity of breeding material, including local land races. Participatory plant breeding is an adequate method, to develop and multiply the most appropriate varieties, also of minor crops neglected by breeding companies.

Time of planting, age of seedling (in the case of transplanting including rice) and spacing are always important to obtain optimum yields. In the case of CA, dry seeding is possible before the rains are established, and where seedlings are transplanted, young seedlings need to be used. For example in the case of transplanted rice, it is now known that the best performance is obtained when the seedling age is between 8 to 12 days at the time transplanting. Similarly, in agroecological production systems such as CA, wider spacing within and between rows than normally recommended by extension services can be desirable for higher yields and factor productivities.

4.1.5 Balanced plant nutrition

Fertilizer rates recommended by national agricultural extension services are in general too high, and do not take into account the situation of individual farms, i.e. soil conditions including nutrient status, requirements of crop varieties, actual rainfall or management practices. Balanced plant nutrition, instead, means replacing nutrients absorbed by crops and lost by soil erosion, leaching or volatilisation; and meeting extra needs of the subsequent crop. Nutrients are applied as organic (farm yard manure or compost) and inorganic fertilizer. Adequate nutrient management avoids losses by leaching or run-off, which pollutes water bodies and is just a monetary loss for the farmer. Depending on rainfall conditions and fertilizer type and rate, fertilizer rates are split. Nitrogen, for example, is applied, before seeding and when plants have the highest demand (e.g. at tillering or grain filling). Localised application, along seed rows (e.g. simultaneously with direct seeders) or into planting pits, increases use efficiency, thus allowing for reduced rates. Farmers should develop a nutrient management plan (NMP). Such a plan describes the correct amount, form, and timing of plant nutrients for optimum yield and minimum impact on water quality.

4.1.6 Integrated pest management; including integrated weed management

Although the use of physical, cultural and biological control methods is the prior choice, the use of pesticides including herbicides, cannot be always avoided. By choosing less toxic and persistent pesticides and by adapting quantities, application methods, and timing to the agronomic and environmental requirements, negative effects of pesticides can be at least reduced. Application equipment (sprayers or fertilizer spreaders) need to be calibrated, appropriate nozzles and pressure applied, drift and run-off of pesticides prevented. Pollution of water bodies, rivers, lakes, dams, has to be avoided by all means, best by respecting a vegetative belt on river banks or lake shores.

Weed control: One of the alleged purpose of tillage in conventional farming is to prepare a clean seed bed, i.e. weed control. When practising no-tillage, weeds have to be controlled either by a ground cover of crop residues and/or cover crops/crop rotations and by mechanical means that is not soil engaging (e.g. with knife roller/slasher), or by herbicides. With good management, e.g. ground cover, sound crop rotation, clean seeds, and optimal planting density, not more herbicides are used compared to conventional agriculture. In order to reduce herbicide use, the use of pre-emergence non-selective herbicides (e.g. glyphosates) should be used with caution and kept to a minimum. Green manures or weeds may be knocked down and desiccated with knife rollers. In most cases the use of post-emergence, selective herbicides, according to weed infestation (species and frequency), is the best choice. To avoid development of resistance, it is recommended changing the herbicides from time to time. Sprayers need to be calibrated, the spray boom brought in the right position, pressure regulated, and special nozzles for herbicide used (bigger droplet size) to avoid drift.

Pest and disease control: A sound crop rotation and a permanent ground cover are also means to reduce pest incidence, as this favours the presence of predators and thus rapid population build-up of pests. Crop rotation is also required to prevent infestation of the young crop by plant diseases surviving on crop residues.

To summarize, actions to protect crops include careful identification of the weeds/pests species; forward plan for crop protection; careful selection of plant protection products (PPP), such as herbicides and pesticides, and the timing of spraying; optimal placement of seeds and fertilizers; field border sanitation; optimized crop rotation, and integrated pest management[1] (IPM) etc.

[1] The definition of IPM: the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment FAO (2011). "AGP-Integrated Pest Management." Retrieved 14 April, 2011, from http://www.fao.org/agriculture/crops/core-themes/theme/pests/ipm/en/.

4.1.7 Efficient water management

Soil and water are the basis for any plant (crop or pasture or tree) production. As in most regions water availability (rain or irrigation water) is, at least temporarily, limited, good agricultural practices aim at maximising water use-efficiency and water productivity. This means reducing water losses caused by run-off, leaching and evaporation, improving water infiltration and storage. The aim is to maximise the percentage of water used for transpiration, i.e., for production. (1) Water infiltration is enhanced by a soil cover, preventing surface sealing and slowing down run-off, and by removal and avoidance of hard pans; (2) water storage or retention is enhanced by a good soil structure and a high organic matter; (3) in dry climates with sporadic rainfall rainwater can be harvested in trenches, in ripped planting lines or planting basins; (4) rainwater evaporation losses are reduced by an early and dense plant stand, and by a soil cover of cover crops or crop residues; (5) in irrigated agriculture, water losses can be significantly reduced by adequate irrigation systems such as deficit irrigation and use of drip irrigation instead of sprinklers or furrow irrigation; (6) planting crops with a deep and dense root system and optimising plant densities contributes to improve water-use efficiency; (7) the stimulation of populations and activity of soil meso- and macrofauna (i.e. earworms and similar) creating deep reaching uninterrupted biopores enhances infiltration of (excess) water. Sound soil management is a precondition of efficient water management. Some relevant practices will be explained more in detail below.

4.1.7.1 Enhanced water infiltration and reduction of evaporation losses by practicing CA

CA practices, primarily minimized soil disturbance and soil cover, result in enhanced water infiltration and reduced evaporation losses. No-tillage stimulates earthworm populations (or similar) by not disturbing the soil and providing sufficient organic matter. Earthworm channels and channels created by decaying roots (of plants with deep reaching root systems) form vertical macropores, which favours not only water infiltration and drainage of excess water but also soil aeration. Even occasional ploughing or mechanical soil disturbance will damage these macropores and thus one of the main positive effects of CA. When using direct seeders, care needs to be taken to ensure that the slot is well closed after sowing and covered with some crop residues. This reduces evaporation losses.

4.1.7.2 In-situ rain water conservation

The dryer the climates the more variable are rainfalls. While rainfall is short in some periods, it is in surplus in other periods. *In situ* rainwater conservation is therefore a strategy to cope with unreliable weather conditions. In Africa's Sahel rainwater conservation has a long tradition. In recent times these old techniques have been revived in some countries. Small-scale farmers in West and Southeast Africa use planting pits to capture and conserve rainwater which improves infiltration. Filling the planting pits with manure or compost improves nutrient availability, leading to significant increases in yields.

In mechanised farming deep ripping of planting lines through the compact soil is another way of increasing infiltration and conserving rainwater.

Planting basins or pits

Planting pits are hand-dug holes 20-30 cm in diameter and 20-25 cm deep, spaced about 1 m apart. Excavated soil is shaped into a small ridge to maximize capture of rainfall and minimize run-off. When available, manure is added to each pit every second year. Seeds are sown directly into the pits at the start of the rainy season, and silt and sand are removed annually. Normally, the highest crop production is during the second year after manure application. In many situations, after two or three seasons, the need for basins and pits may reduce because the whole field becomes increasingly more sponge-like every season.

4.1.7.3 *Deficit irrigation*

In deficit irrigation, water supply is less than the crop's full requirements, and mild stress is allowed during growth stages that are less sensitive to moisture deficiency. The expectation is that any yield reduction will be limited, and additional benefits are gained by diverting the saved water to irrigate other crops.

A six-year study of winter wheat production on the North China Plain showed water savings of 25 percent or more through application of deficit irrigation at various growth stages. In normal years, two irrigations (instead of the usual four) of 60 mm were enough to achieve acceptably high yields and maximize net profits.

In Punjab, Pakistan, a study of the long-term impacts of deficit irrigation on wheat and cotton reported yield reductions of up to 15 percent when irrigation was applied to satisfy only 60 percent of total crop evapotranspiration. In studies carried out in India on irrigated groundnuts, production and water productivity were increased by imposing transient soil moisture-deficit stress during the vegetative phase, 20 to 45 days after sowing. Water stress applied during the vegetative growth phase may have had a favourable effect on root growth, contributing to more effective water use from deeper soil horizons.

Higher water savings are possible in fruit trees, compared to herbaceous crops. In Australia, regulated deficit irrigation of fruit trees increased water productivity by approximately 60 percent, with a gain in fruit quality and no loss in yield.

4.1.7.4 Supplementary irrigation

In dry areas, farmers dependent on rainfall for cereal production can increase yields using supplemental irrigation (SI), which entails harvesting rainwater run-off, storing it in ponds, tanks or small dams, and applying it during critical crop growth stages. One of the main benefits of SI is that it permits earlier planting – while the planting date in rainfed agriculture is determined by the onset of rains, supplemental irrigation allows the date to be chosen precisely, which can improve productivity significantly.

For example, in Mediterranean countries, a wheat crop sown in November has consistently higher yield and shows better response to water and nitrogen fertilizer than a crop sown in January.

The average water productivity of rain in dry areas of North Africa and West Asia ranges from about 0.35 to 1 kg of wheat grain for every cubic metre of water. Applied as supplemental irrigation and along with good management practices, the same amount of water can produce 2.5 kg of grain. The improvement is mainly attributed to the effectiveness of a small amount of water in alleviating severe moisture stress.

When integrated with improved varieties and good soil and nutrition management, supplemental irrigation can be optimized by deliberately allowing crops to sustain a degree of water deficit. Deficit as well as supplementary irrigation has to be well controlled (irrigation controls through plant sensors or capacitance soil probes) in order to avoid flooding, maintain aerobic conditions, and salinity.

4.1.8 Careful management of machines and field traffic to avoid soil compaction

Land management in any form requires access to the land and "traffic" across the land. This traffic, whether it is by humans, animals or machines can lead to compaction of the soil. A soil with a more stable structure is less susceptible to compaction than an instable soil and particularly a freshly tilled soil. Therefore soils under no-tillage are actually less affected by compaction than tilled soils, and the naturally acting soil structuring mechanisms in those soils, such as plant roots and soil macrofauna might repair compactions even in deeper soil layers before they become a problem. In addition, the mulch layer on the soil surface of a not tilled soil acts as an elastic layer reducing the danger of soil compaction.

However, depending on the soil and moisture conditions and particularly on the actual loads applied, even no-till soils can suffer from compaction and adequate care has to be taken. This is particularly the case for large machines, such as self propelled harvesters, which easily reach axle loads exceeding the limits allowed for road traffic. Hence, a safe operation of these machines in terms of avoiding soil compaction is very difficult.

For these cases controlled traffic systems are an adequate solution, in which all field traffic is carried out on permanent tramlines, which become extremely compacted and therefore allow safe access to the field even under adverse weather conditions, while the areas where crops are grown never receive any form of traffic. This results in fuel savings due to the lower rolling resistance when driving on the compacted tramlines, higher yields of the crops from an absolutely compaction free rooting zone and reduced emissions, for example of nitrous oxides due to the better aeration of the soils. Obviously all farm vehicles and machines have to operate at the same track width and with matching working widths, while the actual width of the tyre or drive chain should be as narrow as possible to reduce the field area lost to the tramlines to a minimum. High equipment loads have to be carried along the track, for example with multiple axles or rubber tracks, rather than across the track such as with multiple or floatation tyres.

4.2 INTEGRATED CROP-LIVESTOCK PRODUCTION

Integrated livestock management does not rank amongst the seven recommended management areas described above, as it cannot be practiced everywhere. However, it is a means of maintaining and improving soil health while increasing total farm output.

In conventional farming systems, there is a clear distinction between arable crops and pastureland. With sustainable intensification of crop production, this distinction between fields and pasture no longer exists, since annual crops may be rotated with pasture without the destructive intervention of soil tillage. This “pasture cropping” is an exciting development in a number of countries. In Australia and New Zealand, pasture cropping involves direct-drilling winter crops, such as oats, into pre-dominantly summer-growing pastures of mainly native species. Benefits suggested by field experiments include reduced risk of waterlogging, nitrate leaching and soil erosion.

Grazing on crop residues is a common practice in most low-rainfall regions, where livestock keeping is an important aspect of the risk aversion strategy. While livestock is grazing on natural pasture during the rainy season, it depends on crop residues during the dry season. This grazing on crop residues comes in conflict with the objectives of CA, as crop residues should serve as soil cover. The recommended solution is controlled grazing, i.e. grazing surplus crop residues while leaving sufficient residues as soil cover (>30 percent).

Sources: Sustainable Crop Production Intensification (SCPI), Factsheets 1-5, FAO 2011
Shang-Jung, Lin: Good Conservation Agriculture Practices, FAO 2011

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Conservation Agriculture is actually applied on about 10% of the world's cropland and adoption is growing fast. However, it is not growing fast enough to face the challenges ahead, such as the need to eradicate hunger and food insecurity for a growing population and to address the threats of climate change, land and environmental degradation, resource scarcity and increasing cost of food, production inputs and energy. For "sustainable intensification" strategy as being implemented through Conservation Agriculture to spread faster, it needs not only the accurate application of the concept and principles, but also supportive policies that can facilitate adoption of Conservation Agriculture and reward the adopters for example with payments for environmental services.

This publication provides guidance on such supportive policies, as well as on protocols which would be needed to support schemes of payments for environmental services. It is based on actual field experiences of FAO and GIZ in the promotion of Conservation Agriculture in different world regions and is directed specifically to decision makers in governments for designing and implementing agricultural policies and regulations for sustainable development.

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