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Sustainable Production Intensification in Africa - a climate change perspective –*

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Abstract

Over the next few decades the production has to be doubled to respond to the food demand of a growing population. On the other side the natural resource base for agricultural production is showing increasing signs of degradation. These problems are even more pronounced in Africa. In the past highly intensive agricultural production took a heavy toll on the environment, which was accepted as unavoidable collateral damage, while agriculture which was more respectful to the environment was less productive. The new paradigm of "sustainable production intensification" is recognizing the need for a highly productive agriculture which at the same time positively contributes to environmental services as an element of sustainability.
With regard to climate change this refers to the reduction of the contributions of agricultural production to the release of green house gasses. Adequate agricultural production techniques, based on minimum disturbance of soils (no-till) and enhancement of aerobic conditions in soils can reduce these emissions and eventually even lead to the sequestration of carbon in soils reaching 0.25-2.5 bill t/year. This reduction of GHG emissions results from a better efficiency and reduced losses of production inputs and carbon and is hence not sacrificing high production levels. Sustainable production intensification, based on concepts such as Conservation Agriculture, provide also opportunities for the adaptation to climate change. With these perspectives Conservation Agriculture has a particularly high potential to address the problems of African agriculture. Harnessing the potential of conservation agriculture for carbon sequestration and reduction of GHG emissions for the payment of environmental services to farmers would provide further incentives to farmers for changing to this new way of agriculture.

Keywords: Climate change, Conservation Agriculture, Sustainable Agriculture, Carbon Sequestration, Adaptation

Introduction

Until 2030, food production has to double to satisfy the increasing food demand of a growing world population in qualitative and quantitative terms (FAO 2002). In addition to this demand for food, there is an increasing demand for the production of renewable resources, including bio-energy, based on the same natural resources as food production. So far food production in

* The views expressed in this paper are the personal opinion of the author and do not necessarily quote the official policy of FAO

Africa has only grown at half the rate as the demand. This has also a direct impact on rural livelihoods, since still some 65% of Africa's population lives in rural areas depending on agriculture. At the moment the farming systems applied in Africa are mostly not sustainable. Especially small farmers produce at very low yield levels and yet there is an over exploitation of the natural resources, leading to land degradation as one of the major limiting factors for agricultural production in Africa.
The principal element for the unsustainable use of natural resources leading to soil degradation is the destruction of soil organic matter by burning, uncontrolled grazing and intensive soil tillage. This leads under a climate change scenario to increased vulnerability resulting from the increasing incidence of drought periods on one side and extreme precipitations on the other side (Shaxon et al. 2008).

Sustainable Production Intensification through CA

The new paradigm of "sustainable production intensification" is recognizing the need for a highly productive agriculture which at the same time does not only conserve the natural resource base and environment, but which positively contributes to environmental services as an element of sustainability. One of the most promising technical options to achieve such sustainable production intensification is Conservation Agriculture (CA). CA is currently defined by the UN Food and Agriculture Organization (FAO) as follows (FAO 2008):
CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.
CA is characterized by three principles which are linked to each other in a mutually reinforcing manner, namely:

1. Continuous no- or minimal mechanical soil disturbance (i.e., direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil);
2. Permanent organic-matter soil cover, especially by crop residues and cover crops; and
3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops, including legumes.

While the principles of CA are not new at all, the simultaneous application is creating the above mentioned synergy effects. Zero tillage reduces the mineralization of soil organic matter. In addition to this the soil habitat remains undisturbed and soil life can develop in quantity and quality better than on tilled soils. Vertical continuous macro pores as created by earthworms or roots are not destroyed and remain as drainage channels for rainwater into the subsoil. By not disturbing the soil, the weed seed bank in the soil does not receive the stimulation for germination. This can be perfected even during the seeding process by furrow openers with minimum soil movement allowing the "invisible seeding". The permanent soil cover protects the soil surface from wind, rain, sun and from drying out. In addition the mulch suppresses the germination and growth of weeds, provides habitat for beneficial fauna and feed for the soil life and hence the substrate for the creation of soil organic matter. Allelopathic or other repellent effects of specific covercrops can be used for weed and pest management. The treatment of the mulch cover therefore is part of the weed management under CA. Crop rotation is of particular importance with regard to zero tillage and permanent soil cover. Different crop species with different root systems explore different soil horizons and hence increase the efficiency of the use of soil nutrients. In addition to this a diversified crop rotation is beneficial for avoiding pest and weed problems. When designing the crop rotation it is important that the entire growth period is used by growing some crop, if only for cover.

The synergy effects resulting from the simultaneous application of the CA principles have positive impact on productivity, efficiency of input use as well as on environmental effects and economic profitability of the production system. Soil erosion is reduced to a level below the regeneration of soil. In some cases the soil is literally growing. Under humid temperate conditions the soil growth rate can amount up to 1 mm per year for 30 to 50 years, until the soil organic matter level reaches a new balance (Crovetto 1999). Depending on the supply of organic matter and climate conditions the increase of soil organic matter can reach 0.1-0.2% per year. Soil structure is improved, soil volume available to root growth is increased, providing access to more soil nutrients and improving the fertilizer efficiency (Bot & Benites 2005).

While Conservation Agriculture is reducing farm power requirements in general, this means for a farmer working with her or his hands, that she/he can save 30 – 50 % of the time usually spent for farming. Particularly the heavy work of hoeing and weeding is significantly reduced or even eliminated. With this CA is giving especially weaker people a chance to carry out farming and to maintain their livelihoods from the farm. CA cannot fight HIV/AIDS, but it can help the affected people and mitigate the impact of the disease on their farming income (Bishop-Sambrook 2003). In general CA makes agriculture less unattractive, as it removes the drudgery and improves the farm profit. Since it improves the options for diversification of the farm enterprises CA has also a potential to revert the migration to the urban centres by providing the young generation with new opportunities.

The availability of extra time allows investing into more profitable occupations other than agriculture. This is particularly important for small farmers who cannot make sufficient profit from their farm for a comfortable life. The extra time might also be used for value adding and processing activities within the agricultural production and food chain. The overall income of CA farmers increases and allows them the purchase of household goods or even better houses which improves their lives significantly. In many rural areas where CA has been introduced this is an important factor of empowerment for the rural women. Last but not least, the extra time might allow sending children to school that would normally have to work on the farm (Lange 2005).

The long term results on the production side are a steady increase of the yields with reduced need for inputs. In some cases spectacular yield increases could be observed from the first year on (FAO 2001). Technologies, although not always readily available in Africa, exist for CA at any farm size and mechanization level, from manual hand held equipment through animal traction to fully motorized tractor driven equipment.

CA is spreading in many areas of Africa and particularly in eastern and southern Africa, where it is promoted by FAO and the African Conservation Tillage Network. Building on indigenous and scientific knowledge and innovative equipment design from Latin America, farmers in at least 14 countries are now practicing CA (in Kenya, Uganda, Tanzania, Zambia, Swaziland, Sudan, Madagascar, South Africa, Zimbabwe, Mozambique, Ghana, Burkina Faso, Morocco and Tunisia). In Zambia alone, between 70 000 and 100 000 smallholder farmers are practicing CA (Rumley and Ong, 2007). In the specific context of Africa (where the majority of farmers are resource-poor and rely on less than 1 ha, and there is food insecurity, degradation of soil fertility, drought and irregular rains, shortage of human power for agricultural labour) CA systems are very relevant for addressing the old as well as new challenges of climate change, high energy costs, environmental degradation, no sustainable intensification paradigm other than the standardized tillage-based “green revolution” types relying on the inefficient use of purchased inputs of agro-chemicals. In Africa CA should respond to growing food demand by increasing food production while reducing negative effects on the environment and energy costs, and develop locally adapted technologies that are consistent with CA principles. (Kueneman *et al.*, 2007). A huge potential exists for the adoption of CA in the moist savannah areas. No-tillage systems have also been promoted in Northern Africa under arid conditions, particularly in Morocco and Tunisia. In Tunisia the promotion and development was farmer centred and the area under No-tillage increased from 27 ha on 10 farms in 1999 to nearly 6000 ha on 78 farms in 2007 (Baccouri, 2008). Officially there are several organizations promoting CA in Africa, such as the African Conservation Tillage Network (ACT), the Alliance for a Green Revolution in Africa (AGRA) and others. In 2005 Kenya was hosting the 3rd World Congress on Conservation Agriculture.

Agriculture and Climate Change

Agriculture is both, significant contributor to climate change with a share of nearly 30% of the global green house gas emissions (including those from deforestation and land use change). On the other side managed soils are among the largest carbon stocks on earth and can be harnessed for further carbon sequestration and climate change mitigation through adequate agricultural practices (IPCC 2007). Of the totally 5 bill ha managed land (crop and pasture) with a potential to sequester 0.25-2.5 bill t C/year, 20 % are in Africa.
In addition to the carbon sequestration, CA can reduce the emissions of fossil fuels compared to conventional agriculture by up to 60 per cent (Doets et al. 2000). In addition to this, the use of fertilizer and agrochemicals can be reduced in the long term by 20 per cent. Even the capital investments into heavy machinery such as tractors can be reduced by 50 per cent (Baker et al. 2007; Bistayev 2002). This would reduce the emissions resulting from the production of these inputs. However, the largest contribution to mitigate climate change with CA can be obtained from carbon sequestration and the storage of atmospheric carbon in the soil. The levels of carbon to be captured in the soil vary depending on climate and production system. On average under humid temperate conditions, 0.1-0.5 $t \cdot ha^{-1} \cdot y^{-1}$ of organic carbon can be captured. Under semi arid or tropical conditions, these levels decrease to about 0.05-0.2 $t \cdot ha^{-1} \cdot y^{-1}$ (Baker et al. 2007). This process continues for 25-50 years before a new balance is reached (Reicoscky 2001). Even the emissions of other green house gases such as methane and nitrous oxides can be positively influenced by a change of the cropping practices to CA. These gases occur in smaller volumes but have a much stronger effect as green house gases than carbon dioxide. Methane is for example released from rice fields under anaerobic conditions. CA would change the rice soils into a more aerobic environment without permanent flooding, which would reduce the methane emissions (Belder 2005; Gao 2006). Similar effects can be achieved for nitrous oxides as a result of changes in the nitrogen fertilizer and the soil water management. Suitable selection of fertilizers and placement in the soil can reduce the emissions also under conditions of zero tillage (Izaurralde et al. 2004; Gao 2006).
A Conservation Agriculture Carbon Offset consultation in West Lafayette/USA, organized jointly by FAO and the Conservation Technologies Information Centre (CTIC) with technical assistance from the secretariat of the UNFCCC came to the conclusion that agricultural production following the principles of CA could sequester carbon and significantly reduce other GHG emissions (FAO-CTIC 2008).
Climate change is becoming increasingly a problem for agriculture. Extended drought periods and heavy rainstorms are becoming common features of the weather not only in the tropics (Met Office 2005). CA can help to adapt to these changing and less stable climatic conditions. The increased water infiltration allows soils to absorb most of the rain water even during extreme rainfall events, reducing the risk of erosion and flooding (Saturnino & Landers 2002).

Increased organic matter levels and a better rooting environment in the soil improve water holding capacity of the soils and the ability of plants to survive during drought periods. Yield variations between dry and wet years are less pronounced under CA than under conventional farming practice (Shaxon & Barber 2003, Bot & Benites 2005). Continuous macro pores in the soil increase the water infiltration and hence the absorption capacity of soils during heavy rainstorms. This can be instrumental for the reduction of flood risks (DBU 2002). The increased water infiltration contributes also to a recharge of the aquifer which is of particular importance for regions with falling ground water tables (PDCSR 2005). The increased organic matter levels under CA also provide for better water retention capacity of the soil. For each percent of soil organic matter 150 m^3ha^{-1} of water can be stored in the soil. Loss of soil water is further reduced and in general water savings of 30% under CA are reported compared to conventional cropping systems under similar climatic conditions (Bot & Benites 2005).

Conclusions

Conservation Agriculture as defined by FAO is a base element for the sustainable intensification of crop production. It addresses also many problems faced in African agriculture. At the same time CA allows to include agricultural crop production into the instruments for climate change mitigation since it results in carbon sequestration into soils and it provides the conditions for a reduction of other agricultural green house gas emissions. In addition, CA is a useful tool for adaptation to climate change, making agricultural production systems more resilient to extreme drought, rain and temperature conditions. With these characteristics, agriculture could not only provide for food security and better livelihoods, but also for better environmental services.

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