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Modern concepts of soil conservation

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Abstract

Approaches to soil conservation are in constant evolution and improvement. This paper summarizes some of the modern approaches, ranging from no till to conservation agriculture to sustainable land management. These approaches are not separate, but components of a continuum of conservation approaches applicable at different levels and different scales. No tillage is important at the detailed, farm level, while CA and SLM are important at the farming systems and corporate levels. The successes achieved with no till in Argentina (also Brazil, Paraguay, Uruguay, Mexico, Canada, Australia, and others) illustrate how these concepts relate to each other.

Key Words: Soil conservation, No till, Conservation agriculture, Sustainable land management, Ecosystem goods and services

1 Introduction

Soil is a central component of terrestrial ecosystems, and a fundamental constituent in sustaining life on earth. The degradation of soil represents a loss in ecosystem services and a loss of natural capital assets. The health of terrestrial ecosystems, defined as ecosystem integrity, depends on the ecosystem components and the synergy of processes among them. A healthy ecosystem provides a steady flow of production and environmental goods and services (GEF, 2004), in which the soil plays a key role. Human over-exploitation of these ecosystems results in considerable degradation (natural capital loss), and while this can sometimes be justified to produce greater gains in other services (this is called development), often more degradation of ecosystem services takes place than is in the best interest of society (UNEP, 2005). Recent estimates are that this degradation will continue as a consequence of a likely three to six-fold increase in global GDP by 2050, even while global populations are expected to level off (UNEP, 2005).

Agricultural land uses occupy 36.5% of the earth's land mass (FAOSTAT, 2008). This large area, once considered only for food production, is now viewed as increasingly important for providing local and global environmental goods and services. The quality and volume of these services depend not only on the amount of land occupied (the more land the greater the impacts), but also on the land management strategies and practices used in production.

Traditional agricultural practices are based on ploughing and tilling the land in preparation of the seed bed. These practices, however, have been shown to be highly destructive of the soil, with the result that about 24% of global agricultural land is degraded (Bai et al., 2008). Land degradation reduces the soil's short and long term production capacity, and these are serious concerns considering the food production requirements of growing global populations and a global GDP which is expected to triple by 2050.

The traditional approach to soil tillage is gradually being replaced by new paradigms centered on conserving and improving the soil, while enhancing productivity, profits, and environmental benefits. Most of these approaches are based on procedures of no-tillage, as well as the broader concepts of conservation agriculture and sustainable land management. These concepts are not separate, but parts of a continuum of land management practices ranging

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from detailed soil management practices such as no-tillage, to the broadening concepts, principles, and objectives of conservation agriculture and sustainable land management. This spectrum of land management options enables and promotes achievement of a more sustainable kind of agriculture than what we have today.

Although these new concepts are exciting and show much promise in gaining a more sustainable agriculture, they are also more knowledge dependant than those of the past. Whereas, past approaches were often technology based, i. e. better cultivars, better fertilization, etc. , the new concepts require better understanding of the processes and approaches being promoted. This paper is an attempt to provide some background and clarity on these issues, and it is an attempt to demonstrate the complementarity among the concepts. Each new approach is described briefly, and then all are linked into a hierarchical network focused on promoting a more environmentally friendly and economically viable global agriculture. It must be noted, however, that everything begins by first promoting an environmentally healthy soil.

2 Modern concepts of soil conservation

2.1 *No tillage (also called zero till, direct drilling)*

Under no-till, soil disturbance is virtually eliminated. Only a tiny slot (or a small hole in hand held planters) is made during the planting operation so that the seed (and eventually starter fertilizers) can be placed in intimate contact with the soil, promoting germination. Only the grains are harvested, while the rest of the plant (plant material other than grains) are left on the surface (Peiretti, 2003). Gradually, an organic mulch is developed on the soil surface, which is eventually converted to stable soil organic matter (Dumanski et al., 2006). The increase in organic matter results from the combination of eliminating soil disturbance, reducing oxidation of soil organic materials (stubble), increased biomass production from improved crop yields, and greater diversity of organic materials from increased rotation and cover crops, and reduced erosion. Commonly, surface soil temperatures are slightly depressed, while soil water holding capacity is increased. These conditions are particularly important in the tropical and semi-tropical areas. No tillage can be practised on both large and small farming systems.

No tillage is effective in mitigating many of the negative on-farm and off-site effects of conventional tillage, principally erosion, organic matter loss, reduced biodiversity and reduced runoff. These conditions are replaced with permanent soil cover, improvements in soil structure, improved organic matter status, improved water use efficiency, and improved soil biology and nutrient cycling. The surface mulch layer creates a stable microbial ecology, and with time, the microbial and macro-faunal (earthworms) populations become more like those of natural soils. Their activity greatly enhances the assimilation and transfer of surface organic materials into deeper soil layers, and in the process, creating physically-robust channels to enhance water penetration and dispersion into the soil.

In years of average or above average rainfall, the improved soil conditions ensure crop yields comparable to those with conventional tillage, but often with higher fertilizer use efficiency. In dry years, the improved soil moisture, aggregation, and organic matter status of the no till soils often ensure some degree of yield even when conventionally tilled soils do not (Peiretti, 2006). This provides some degree of drought proofing in areas being affected. Profit margins with no tillage are normally better than under conventional tillage systems, and this enhances the sustainability and future continuity of the CA farming systems.

No till (including controlled traffic where all in-field traffic traverse only specified wheel or foot tracks), is highly compatible to precision treatment of field conditions. Procedures include differential fertilizer applications according to nutrient requirements, spot spraying for weed control, controlled traffic in association with no till, etc. As a consequence, wetlands, water bodies, habitats, and stream courses in agricultural areas can be better protected. In high input systems, precision treatment is becoming popular because of the improved efficiencies of operation and reduced input costs. At the same time, these principles have been used for many centuries in low input systems to optimize local nutrient, soil moisture, and sunshine conditions, as well as natural plant symbiosis.

No tillage also promotes the environmental integrity of the soil systems and the maintenance of environmental services. The system enhances sequestration of atmospheric carbon and contributes to mitigation of climate change. Soil carbon sinks are enriched, due to higher yields and increased biomass, as well as by reducing organic carbon losses from soil erosion. Also fuel use and tractor hours are reduced up to 75%, with further reductions in greenhouse gas emissions. Other environmental benefits include reduced siltation, eutrophication and pesticide contamination of rivers and dams.

Concepts often confused with no-till include variants of Conservation Tillage, such as mulch tillage (where 35% or more of surface residues are maintained), ridge tillage where planting is achieved on specially prepared but tilled ridges, vertical tillage normally carried out with shank tillage tools (keeping some proportion of litter on the surface), minimum tillage implemented with tilling tools such as discs or flexible shanks, etc. Although all variants are intended to reduce tillage intensity, the impacts of these practices on soil quality are radically different.

2.2 *Conservation Agriculture (CA)*

In deference to other approaches, Conservation Agriculture (CA) does not promote a specific technology but rather a series of principles and general practices to achieve conservation objectives. CA is not a prescription or a standard technology, but an approach based on concepts of minimal soil disturbance, permanent soil cover, and crop rotation or association (FAO, 2001). This is in recognition of the fact that global agriculture is practiced in many different ecosystems, and technologies have to be carefully tailored to these to be successful. In this regard, conservation agriculture is similar to the concepts of sustainable land management.

CA is application of modern agricultural technologies to improve production while concurrently protecting and enhancing the land resources on which production depend. CA encourages application of modern technologies that enhance the quality and ecological integrity of the soil. No tillage, along with other soil conservation practices, are the cornerstones of CA (Dumanski et al., 2006). A permanent soil cover is maintained with cover crops, crop residues or mulch. Crop rotations or associations may include crop sequences, intercropping, and relay cropping or mixed crops. With proper adaptation, the principles of CA are applicable to extensive grain and oilseeds production, pastures and rangeland, as well as high value, intensive cropping including horticulture and agroforestry.

CA aims to increase land productivity and yield stability, reduce production costs and drudgery in land preparation and management, and improve the physical, hydrological and biological qualities of the land. CA is based on optimizing (rather than maximizing) yields and profits, to achieve a balance of agricultural, economic and environmental benefits (Dumanski et al., 2006). It advocates that the combined social and increasingly economic benefits gained from combining production and protecting the environment, including reduced input and labor costs, are greater than those from production alone. With CA, farming communities become providers of more healthy living environments for the wider community.

Application of traditional knowledge of soil husbandry gained from generations of successful farmers, and the implementation by farmers of complementary, synergetic soil husbandry practices, enhance the capacity of farmers to innovate and adjust to evolving conditions and ensure the sustainability of the farming system.

CA is best achieved through community driven development processes, whereby local communities and farmer associations identify, decide, and implement the best options for conservation agriculture in their location. Local, regional and national farmer associations, individuals and communities are the main actors involved in promoting CA. International and national CA farmer associations that assist and encourage farmers to adopt CA through workshops and farmer-to-farmer training, also greatly enhance the capacity of local farmers to identify, capture and promote opportunities for improved agricultural and environmental management (FAO, 2001). In most cases, technical backstopping from conservation professionals is necessary for successful application of CA (Dumanski et al., 2006).

Principles of CA

CA emphasizes that the soil contains, supports, and sustains life on the planet. In particular, it recognizes the importance of the upper 0 – 20 cm of soil as the most active zone, but also the zone most vulnerable to erosion and degradation. Most environmental functions and services that are essential to support terrestrial life on the planet are concentrated in the micro, meso, and macro fauna and flora which live and interact in this zone. It is also the zone where human activities of land management have the most immediate, and potentially the greatest impact. By protecting this critical zone, we ensure the health, vitality, and sustainability of life on this planet.

The principles of CA and the activities to be supported are described as follows (Dumanski, 2006):

- *Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through no tillage system.*
- *Promoting a healthy "living soil" through crop rotations, cover crops, and the use of integrated pest management technologies.*
- *Promoting the application of fertilizers, pesticides, herbicides, and fungicides in balance with nutrient losses due to crop production.* This principle is based on feeding the soil rather than fertilizing the crop.
- *Promoting precision placement of crop inputs to reduce input costs, optimize efficiency of operations, and prevent environmental damage.*
- *Promoting legume fallows (including herbaceous and tree fallows where suitable), as well as promoting*

composting and the use of manures and other organic soil amendments.

- *Promoting value added production for food, fiber, fruit, energy and medicinal purposes. Value added production implies producing for the market.*

2.3 *Sustainable land management (SLM)*

The concept of Sustainable Land Management (SLM) expands on CA to include dimensions of economics, markets, profits and sustainability. SLM promotes value added production, food sufficiency, and poverty reduction, through improved crop and animal production and production in relation to market opportunities. It can be achieved through better management of field crops, agroforestry, specialty crops, and permanent cropping systems.

The concepts of SLM were first identified and described by Smyth and Dumanski (1993). They defined SLM as "combines technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns, so as to simultaneously:

- maintain and enhance production (productivity)
- reduce the level of production risk, and enhance soil capacity to buffer against degradation processes (stability/resilience)
- protect the potential of natural resources and prevent degradation of soil and water quality (protection)
- be economically viable (viability)
- be socially acceptable, and assure access to the benefits from improved land management (acceptability/equity)."

These criteria, productivity, resilience, protection, economic viability, and social acceptability, are the basic principles or pillars on which SLM is being developed.

The concepts of SLM have been adopted and applied by several international development agencies, including the World Bank and the GEF. The GEF sponsored TerrAfrica program (GEF, 2005) defines sustainable land management as "the adoption of land use systems that, through appropriate management practices, enable land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources". An earlier definition developed at the Earth Summit, Johannesburg, 2002, identifies SLM as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions". SLM encompasses other established approaches such as soil and water conservation, conservation agriculture, natural resources management, and integrated ecosystem management. It promotes integration of social, economic, physical and biological needs and values, to achieve a more holistic, productive, and healthy ecosystem.

Application of SLM requires collaboration and partnership at all levels, including land users, technical experts and policy makers, to ensure that the causes of the degradation and corrective measures are properly identified, and that the policy and regulatory environment enables the adoption of the most appropriate management measures. The GEF (2005) identified four common principles for successful implementation of SLM:

- land user-driven and participatory approaches;
- integrated use of natural resources at ecosystem and farming system levels;
- mulitilevel and mulitstakeholder involvement;
- targeted policy and institutional support, including development of incentive mechanisms for SLM adoption and income generation at the local level.

SLM is an imperative for sustainable development and plays a key role in harmonizing the complimentary, yet historically conflicting goals of production and environment. Thus, one of the most important aspects of SLM is this critical merger of agriculture and environment through twin objectives:

- maintaining long term productivity of the ecosystem functions (land, water, biodiversity)
- increasing productivity (quality, quantity, diversity) of goods and services, and particularly safe and healthy food.

To operationalize the sustained combination of these twin SLM objectives, it is essential to understand the drivers and causes of land degradation, and to take into account issues of current and emerging risks.

SLM recognizes that people (human resources) and the natural resources on which they depend, directly or indirectly, are inextricably linked. Rather than treating each in isolation, all ecosystem elements are considered together, in order to obtain multiple ecological and socio-economic benefits (GEF, 2005). The concepts of SLM have been linked to the UN International environment conventions, Desertification, Climate Change, Biodiversity, by

Cowe et al. (2011).

3 Discussion and conclusions

The various approaches to soil conservation, including no tillage, CA, and SLM, are not separate concepts, but components of a continuum of conservation approaches applicable at different levels. No tillage is important at the detailed, farm level, while CA and SLM are important at the farming systems and corporate levels.

Recognition of the different levels of soil conservation does not imply promotion of a specific technology but rather a process of application and adoption. Local farmer knowledge, innovative farmers, research backstopping, and farmer associations are all necessary elements in adoption of the principles.

No-tillage, Conservation Agriculture (CA) and Sustainable Land Management (SLM) provide direct benefits to agricultural and environmental issues of local and global importance. These include land degradation, air quality, climate change, biodiversity and water quality. CA and SLM relate directly to the United Nations Framework Convention on Climate Change, the International Convention on Biodiversity, the International Convention to Control Desertification, and the various agreements on international waters.

Soil are an integral component of natural and converted ecosystems (cropland, pasturelands, woodlands), and an important part of the natural mosaic of land uses on the earth's terrestrial surface (Dumanski et al., 2006). Agro-ecosystems and other managed ecosystems experience different pressures, energy flows, and dynamics than natural systems, and these have to be better understood not only in terms of capital return (yield), but also as a consequence of human interventions on natural systems.

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