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# No-tillage Seeding in Conservation Agriculture

## Second Edition

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# 2 The Benefits of No-tillage

Don C. Reicosky and Keith E. Saxton

Intensive tillage farming reduces soil organic matter and degrades soil quality – no-tillage farming enhances soil quality and sustains long-term agriculture.

## Introduction

Sustainable food and fibre production of any given field and region requires that the farming methods be economically competitive and environmentally friendly. To achieve this result requires adopting a farming technology that not only benefits production but provides an environmental benefit to the long-term maintenance of the soil and water resources upon which it is based. We must reduce pollution and use our resources in line with the earth's carrying capacity for sustainable production of food and fibre.

The responsibility of sustainable agriculture lies on the shoulders of farmers to maintain a delicate balance between the economic implications of farming practices and the environmental consequences of using the wrong practices. This responsibility entails producing food and fibre to meet the increasing population while maintaining the environment for a sustained high quality of life. The social value of an agricultural community is not just in production, but in producing in harmony with nature for improved soil, water and air quality and biological diversity.

Sustainable agriculture is a broad concept that requires interpretation at the regional and local level. The principles are captured in the definition reported by El-Swaify (1999) as: 'Sustainable agriculture involves the successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the quality of the environment and conserving natural resources.'

Conservation agriculture, especially no-tillage (direct seeding), has been proved to provide sustainable farming in many agricultural environments virtually around the world. The conditions and farming scales vary from humid to arid and vegetable plots to large prairie enterprises. All employ and adapt very similar principles but with a wide variety of machines, methods and economics.

The benefits of performing crop production with a no-tillage farming system are manyfold. Broad subjects discussed here only begin to provide the science and results learned over recent decades of exploring and developing this farming method. In addition to improved production and soil and water resource protection, many other benefits accrue. For example, it saves time and money, improves timing of planting

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and harvesting, increases the potential for double cropping, conserves soil water through decreased evaporation and increased infiltration, reduces fuel, labour and machinery requirements and enhances the global environment.

## Principles of Conservation Agriculture

Conservation agriculture requires implementing three principles, or pillars, as illustrated in Fig. 2.1. These are: (i) minimum soil tillage disturbance; (ii) diverse crop rotations and cover crops; and (iii) continuous plant residue cover. The main direct benefit of conservation agriculture and direct seeding is increased soil organic matter and its impact on the many processes that determine soil quality. The foundation underlying the three principles is their contribution and interactions with soil carbon, the primary determinant of long-term sustainable soil quality and crop production.

Conservation tillage includes the concepts of no-tillage, zero-tillage and direct seeding as the ultimate form of conservation agriculture. These terms are often used interchangeably to denote minimum soil disturbance. Reduced tillage methods, sometimes referred to as conservation tillage, such as strip tillage, ridge tillage and mulch tillage, disturb a small volume of soil and partially mix the residue with the soil and are intermediate in their soil quality effects. These terms define the tillage equipment and operation characteristics as they relate to the soil volume disturbed and the degree of soil–residue mixing. Intensive inversion tillage, such as that from mouldboard-ploughing, disc-harrowing and certain types of powered rotary tillage, is not a form of conservation tillage. No-tillage and direct seeding are the primary methods of conservation tillage to apply the three pillars of conservation agriculture for enhanced soil carbon and its associated environmental benefits.

True soil conservation is largely related to organic matter, i.e. carbon, management.

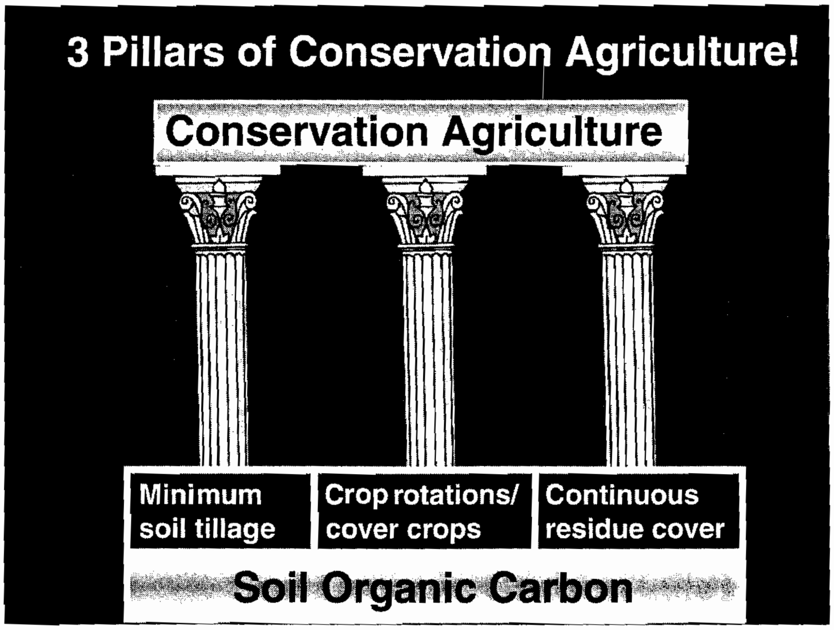

**Fig. 2.1.** Schematic representation of the three pillars or principles of conservation agriculture supported by a foundation of soil carbon.

By nothing more than properly managing the carbon in our agricultural ecosystems, we can have less erosion, less pollution, clean water, fresh air, healthy soil, natural fertility, higher productivity, carbon credits, beautiful landscapes and sustainability. Dynamic soil quality encompasses those properties that can change over relatively short time periods, such as soil organic matter, soil structure and macroporosity. These can readily be influenced by the actions of human use and management within the chosen agronomic practices. Soil organic matter is particularly dynamic, with inputs of plant materials and losses by decomposition.

## Crop Production Benefits

Producing a crop and making an economic profit are universal goals of global farming. Production by applying no-tillage methods is no different in these goals, but there are definite benefits for the achievement, which we outline in this chapter. But these benefits only occur with fully successful no-tillage farming. There are certainly obstacles and risks in moving from traditional tillage farming, which has been the foundation technology for centuries, as outlined in Chapter 3.

Acceptable crop production requires an adequate plant stand, good nutrition and moisture with proper protection from weed, insect or disease competition. Achieving the plant stand in untilled, residue-covered soils is the first major obstacle, a particular challenge in modern mechanized agriculture, but certainly surmountable, as explained in the core of this text. Providing adequate nutrition and water for full crop potentials is readily achieved with the benefits of no-tillage, as discussed below.

Weed-control methods, by necessity, shift to dependence on chemicals, flame-weeding, mechanical crushing or hand picking for full no-tillage farming to stay within the goal of minimum soil disturbance. Chemical developments in recent decades have made great strides in their effectiveness, environmental friendliness and economic feasibility. Supplemental techniques of mowing, rolling and crushing without soil disturbance are showing significant promise to reduce weed presence and increase the benefit of cover crops and residues. Experience has shown that controlling insects and diseases has generally been less of a problem with no-tillage, even though there are often dire predictions about the potential impact of surface residues harbouring undesirables. As with weeds, crop health and pest problems are not likely to be avoided but may well shift to new varieties and species with the change in the field environment.

As a result of these developments and skilled applications, it has been repeatedly shown that crop production can be equalled and exceeded by no-tillage farming compared with traditional tillage methods. Because many soils have been tilled for many years, it is not uncommon to experience some yield reduction in the first few no-tillage years, largely because, as discussed later, it takes time for the soil to rebuild into a higher quality. This 'transition period reduction' can often be overcome or even averted with increased fertility, strategic fertilizer banding with drill openers and careful crop selection.

The full benefit of no-tillage comes in the reduced inputs. Most notable are the reduced inputs by minimizing labour and machine hours spent establishing and maintaining the crop. Reduced machine costs alone are significant, since all tillage equipment is dispensable. True no-tillage farming requires only an effective chemical sprayer, seeding–fertilizing drill and harvester.

With no seedbed preparation of the soil by tillage, seed drilling has become the major limitation to many efforts to successfully change to no-tillage farming. Modifying drills used in tillage farming has generally not been very successful, resulting in undesirable crop stands for optimum production. Many were not equipped to provide simultaneous fertilizer banding; thus it had to be provided by a supplemental minimum-tillage machine or, in the worst case, surface-applied, where it was very ineffective and stimulated weed growth.

Fortunately, drill development has progressed to now provide acceptable seeding in many cases, but, as described in later chapters, many still do not fully meet all desirable attributes, especially in relation to the amount of soil disturbance they create.

As a result of science and technique developments of recent years, no-tillage crop production now not only is feasible but has significant economic benefits. Combining and multiplying this result by the further benefits of soil and environmental qualities make no-tillage farming a highly desirable method of crop production. Further, many are now finding personal and social benefits from the reduced labour inputs, which remove much of the demanded time and drudgery often associated with traditional farm life. A common remark by successful no-tillage farmers is 'It has brought back the fun of farming.'

## Increased organic matter

Understanding the role of soil organic matter and biodiversity in agricultural ecosystems has highlighted the value and importance of a range of processes that maintain and fulfil human needs. Soil organic matter is so valuable for its influence on soil organisms and properties that it can be referred to as 'black gold' because of its vital role in physical, chemical and biological properties and processes within the soil system.

The changes of these basic soil properties, called 'ecosystem services', are the processes by which the environment produces resources that sustain life and which we often take for granted. An ecosystem is a community of animals and plants interacting with one another within their physical environment. Ecosystems include physical, chemical and biological components such as soils, water and nutrients that support the biological organisms living within them, including people. Agricultural ecosystem services include production of food, fibre and biological fuels, provision of clean air and water, natural fertilization, nutrient cycling in soils and many other fundamental life support services. These services may be enhanced by increasing the amount of carbon stored in soils.

Conservation agriculture through its impact on soil carbon is the best way to enhance ecosystem services. Recent analyses have estimated national and global economic benefits from ecosystem services of soil formation, nitrogen fixation, organic matter decomposition, pest biocontrol, pollination and many others. Intensive agricultural management practices cause damage or loss of ecosystem services, by changing such processes as nutrient cycling, productivity and species diversity (Smith *et al.*, 2000). Soil carbon plays a critical role in the harmony of our ecosystems providing these services.

Soil carbon is a principal factor in maintaining a balance between economic and environmental factors. Its importance can be represented by the central hub of a wagon wheel, a symbol of strength, unity and progress (Reicosky, 2001a). The 'spokes' of this wheel in Fig. 2.2 represent incremental links to soil carbon that lead to the environmental improvement that supports total soil resource sustainability. Many spokes make a strong wheel. Each of the secondary benefits that emanate from soil carbon contributes to environmental enhancement through improved soil carbon management. Soane (1990) discussed several practical aspects of soil carbon important in soil management. Some of the 'spokes' of the environmental sustainability wheel are described in the following paragraphs.

Based on soil carbon losses with intensive agriculture, reversing the decreasing soil carbon trend with less tillage intensity benefits a sustainable agriculture and the global population by gaining better control of the global carbon balance. The literature holds considerable evidence that intensive tillage decreases soil carbon and supports increased adoption of new and improved forms of no-tillage to preserve or increase storage of soil organic matter (Paustian *et al.*, 1997a, b; Lal *et al.*, 1998). The environmental and economic benefits of conservation agriculture and no-tillage demand their consideration in the development of improved soil carbon storage practices for sustainable production.

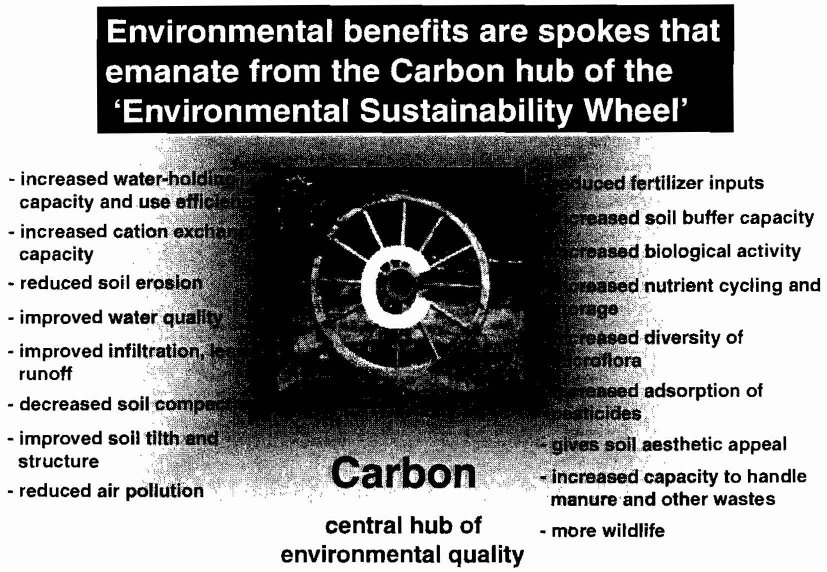

**Fig. 2.2.** Environmental sustainability wheel with benefits emanating from the soil carbon hub.

## Increased available soil water

Increased soil organic matter has a significant effect on soil water management because of increased infiltration and water-holding capacity. Enhanced soil water-holding capacity is a result of increased soil organic matter, which more readily absorbs water and releases it slowly over the season to minimize the impacts of short-term drought. Hudson (1994) showed that, for some soil textures, for each 1% weight increase in soil organic matter, the available water-holding capacity in the soil increased by 3.7% volume. Other factors being equal, soils containing more organic matter can retain more water from each rainfall event and make more of it available to plants. This factor and the increased infiltration with higher organic matter and the decreased evaporation with crop residues on the soil surface all contribute to improved water use efficiency.

Increased organic matter is known to increase soil infiltration and water-holding capacity, which significantly affect soil water management. Under these situations, crop residues slow runoff water and increase infiltration by earthworm channels, macropores and plant root holes (Edwards *et al.*, 1988). Water infiltration is two to ten times faster in soils with earthworms than in soils without earthworms (Lee, 1985).

Soil organic matter contributes to soil particle aggregation, which makes it easier for water to move through the soil and enables plants to use less energy to establish root systems (Chaney and Swift, 1984). Intensive tillage breaks up soil structure and results in a dense soil, making it more difficult for plants to fully access the nutrients and water required for their growth and production. No-tillage and minimum-tillage farming allows the soil to restructure and accumulate organic matter for improved plant water and nutrient availability.

## Reduced soil erosion

Crop residue management practices have included many agricultural practices to reduce soil erosion runoff and off-site sedimentation. Soils relatively high in C, particularly with crop residues on the soil surface, very effectively increase soil organic matter and reduce soil erosion loss. The primary role of soil organic matter to reduce soil erodibility is to stabilize the surface aggregates through reduced crust formation and surface sealing, resulting in less runoff (Le Bissonnais, 1990). Reducing or eliminating runoff that carries sediment from fields to rivers and streams is a major enhancement of environmental quality. Under these situations, crop residues act as tiny dams that slow down water runoff from fields, allowing the water more time to soak into the soil.

Crop residues on the surface not only help hold soil particles in place but keep associated nutrients and pesticides on the field. The surface layer of organic matter minimizes herbicide runoff and, with conservation tillage, herbicide leaching can be reduced by as much as half (Braverman *et al.*, 1990).

Increased soil organic matter and crop residues on the surface will significantly reduce wind erosion (Skidmore *et al.*, 1979). Depending on the amount of crop residues left on the soil surface, soil erosion can be reduced to near zero as compared with that from an unprotected, intensively tilled field. Wind or water soil erosion causes soil degradation and variability to the extent of a resulting crop yield decline.

Papendick *et al.* (1983) reported that the original topsoil on most hilltops had been removed by tillage erosion in the Palouse region of the Pacific Northwest of the USA. Mouldboard ploughs were identified as the primary cause, but all tillage implements will contribute to this problem (Groves *et al.*, 1994; Lobb and Kachanoski, 1999). Soil translocation from mouldboard plough-based tillage can be greater than soil loss tolerance levels (Lindstrom *et al.*, 1992; Groves *et al.*, 1994; Lobb *et al.*, 1995, 2000; Poesen *et al.*, 1997). Soil is not directly lost from the fields by tillage translocation; rather, it is moved away from the convex slopes and deposited on concave slope positions.

Lindstrom *et al.* (1992) showed that soil movement on a convex slope in southwestern Minnesota, USA, could result in a sustained soil loss level of approximately 30 t/ha/year from annual mouldboard-ploughing. Lobb *et al.* (1995) estimated soil loss in southwestern Ontario, Canada, from a shoulder position to be 54 t/ha/year from a tillage sequence of mouldboard-ploughing, tandem-discing and C-tine cultivating. In this case, tillage erosion, as estimated through resident caesium-137, accounted for at least 70% of the total soil loss. The net effect of soil translocation from the combined effects of tillage and water erosion is an increase in spatial variability of crop yield and a likely decline in soil carbon, related to lower soil productivity (Schumacher *et al.*, 1999).

## Enhanced soil quality

Soil quality is the fundamental foundation of environmental quality. Soil quality is largely governed by soil organic matter (SOM) content, which is dynamic and responds effectively to changes in soil management, tillage and plant production. Maintaining soil quality can reduce the problems of land degradation, decreasing soil fertility and rapidly declining production levels that occur in large parts of the world needing the basic principles of good farming practice.

Soil compaction in conservation tillage farming is significantly reduced by the reduction of traffic and increased SOM (Angers and Simard, 1986; Avnimelech and Cohen, 1988). Soane (1990) presented several mechanisms by which soil 'compactibility' can be affected by SOM:

1. Improved internal and external binding of soil aggregates.
2. Increased soil elasticity and rebounding capabilities.
3. Reduced bulk density due to mixing organic residues with the soil matrix.
4. Temporary or permanent existence of root networks.
5. Localized change of electrical charge of soil particle surfaces.
6. Change in soil internal friction.

While most soil compaction occurs during the first vehicle trip over the tilled field, reduced weight and horsepower requirements associated with no-tillage can also help minimize compaction. Additional field traffic required by intensive tillage compounds the problem by breaking down soil structure. Maintenance of SOM contributes to the formation and stabilization of soil structure. The combined physical and biological benefits of SOM can minimize the effect of traffic compaction and result in improved soil tilth.

While it is commonly known that tillage produces a well-fractured soil, sometimes requiring several tillage passes, it is a misconception that this is a well-aggregated, healthy soil. These soils never fare well when judged against modern knowledge of high 'soil quality'. A tilled soil is poorly structured, is void of many microorganisms and has poor water characteristics, just to name a few characteristics. As soils are farmed without tillage and supplied with residues, they naturally improve in overall quality, again support many microorganisms and become 'mellow' to the point of being easily penetrated by roots and earthworms. This transition takes several years to accomplish but invariably occurs given the opportunity.

Many traditional experienced farmers will often ask, 'How many years of no-tillage are possible before the soil becomes so compact as to require tillage?' No-tillage experience has shown exactly the opposite effect: once a no-tilled soil has regained its quality, it will continue to resist compaction and any subsequent tillage will cause undue damage. Most soils will continue to build organic matter and improve in quality criteria for years into the practice of no-tillage farming if the sequence is not broken by the thunderous effect of tillage.

### Improved nutrient cycles

Improved soil tilth, structure and aggregate stability enhance the gas exchange and aeration required for nutrient cycling (Chaney and Swift, 1984). Critical management of soil airflow, with improved soil tilth and structure, is required for optimum plant function. It is the combination of many factors that results in comprehensive environmental benefits from SOM management. The many attributes suggest new concepts on how we should manage the soil for long-term aggregate stability and sustainability.

Ion adsorption or exchange is one of the most significant nutrient cycling functions of soils. Cation exchange capacity (CEC) is the quantity of exchange sites that can absorb and release nutrient cations. SOM can increase this capacity of the soil from 20 to 70% over that of the clay minerals and metal oxides present. In fact, Crovetto (1996) showed that the contribution of organic matter to the cation exchange capacity exceeded that of the kaolinite clay mineral in the surface 5 cm of his soils. Robert (1996) showed that there was a strong linear relationship between organic carbon and the cation exchange capacity of his experimental soil. The capacity was increased fourfold with an organic carbon increase from 1 to 4%. The toxicity of other elements can be inhibited by SOM, which has the ability to adsorb soluble chemicals. Adsorption by clay minerals and SOM is an important means by which plant nutrients are retained in crop rooting zones.

Increased infiltration and concerns over the use of nitrogen in no-tillage agriculture require an understanding of the biological, chemical and physical factors controlling nitrogen losses and the relative impacts of contrasting crop production practices on nitrate leaching from agroecosystems. Domínguez *et al.* (2004) evaluated the leaching of water and nitrogen in plots with varying earthworm populations in a maize system. They found that the total flux of nitrogen in soil leachates was 2.5-fold greater in plots with increased earthworm populations than in those with lower populations. Their results are dependent on rainfall amounts, but do indicate that earthworms can increase the leaching of water and inorganic nitrogen to greater depths in the profile, potentially increasing nitrogen leaching from the system. Leaching losses were lower on the organically fertilized plots, attributed to higher immobilization potential.

### Reduced energy requirements

Energy is required for all agricultural operations. Modern, intensive agriculture requires much more energy input than traditional farming methods since it relies on the use of fossil fuels for tillage, transportation, grain drying and the manufacture of fertilizers, pesticides and equipment used to apply agricultural inputs and for generating electricity used on farms (Frye, 1984). Reduced labour and machinery costs are economic considerations that are frequently given as additional reasons to use conservation tillage practices.

Practices that require lower energy inputs, such as no-tillage versus conventional tillage, generally result in lower inputs of fuel and a consequent decreases of $CO_2$-carbon emissions into the atmosphere per unit of land area under cultivation. Emissions of $CO_2$ from agriculture are generated from four primary sources: manufacture and use of machinery for cultivation, production and application of fertilizers and pesticides, the soil organic carbon that is oxidized following soil disturbance (which is largely dependent on tillage practices) and energy required for irrigation and grain drying.

A dynamic part of soil carbon cycling in conservation agriculture is directly related to the 'biological carbon' cycle, which is differentiated from the 'fossil carbon' cycle. Fossil carbon sequestration entails the capture and storage of fossil-fuel carbon prior to its release to the atmosphere. Biological carbon sequestration entails the capture of carbon from the atmosphere by plants. Fossil fuels (fossil carbon) are very old geologically, as much as 200 million years. Biofuels (bio-carbon) are very young geologically and can vary from 1 to 10 years in age and as a result can be effectively managed for improved carbon cycling. One example of biological carbon cycling is the agricultural production of biomass for fuel. The major strength of biofuels is the potential to reduce net $CO_2$ emissions to the atmosphere. Enhanced carbon management in conservation agriculture may make it possible to take $CO_2$ released from the fossil carbon cycle and transfer it to the biological carbon cycle to enhance food, fibre and biofuel production, for example, using natural gas fertilizer for plant production.

West and Marland (2002) conducted a carbon and energy analysis for agricultural inputs, resulting in estimates of net carbon flux for three crop types across three tillage intensities. The analysis included estimates of energy use and carbon emissions for primary fuels, electricity, fertilizers, lime, pesticides, irrigation, seed production and farm machinery. They estimated that net $CO_2$-carbon emissions for crop production with conservation, reduced and no-tillage practices were 72, 45 and 23 kg carbon/ha/year, respectively.

Total carbon emission values were used in conjunction with carbon sequestration estimates to model net carbon flux to the atmosphere over time. Based on US average crop inputs, no-tillage emitted less $CO_2$ from agricultural operations than did conventional tillage, with 137 and 168 kg of carbon/ha/year, respectively. The effect of changes in fossil-fuel use was the dominant factor 40 years after conversion to no-tillage.

This analysis of US data suggests that, on average, a change from conventional tillage to no-tillage will result in carbon sequestration in soil, plus a saving in $CO_2$ emissions from energy use in agriculture. While the enhanced carbon sequestration will continue for a finite time until a new equilibrium is reached, the reduction in net $CO_2$ flux to the atmosphere, caused by the reduced fossil-fuel use, can continue indefinitely, as long as the alternative practices are continued.

Lal (2004) recently provided a synthesis of energy use in farm operations and its conversion into carbon equivalents (CE). The principal advantage of expressing energy use in terms of carbon emission as kg CE lies in its direct relation to the rate of enrichment of atmospheric $CO_2$ concentration. The operations analysed were carbon-intensive agricultural practices that included tillage, spraying chemicals, seeding, harvesting, fertilizer nutrients, lime, pesticide manufacture and irrigation. The emissions for different tillage methods were 35.3, 7.9 and 5.8 kg CE/ha for conventional tillage, chisel tillage or minimum tillage and no-tillage methods of seedbed preparation, respectively.

Tillage and harvest operations account for the greatest proportion of fuel consumption within intensive agricultural systems.

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Frye (1984) found fuel requirements using reduced tillage or no-tillage systems were 55 and 78%, respectively, of those used for conventional systems that included mouldboard-ploughing. On an area basis, savings of 23 kg/ha/year in energy carbon resulted from the conversion of conventional tillage to no-tillage. For the 186 million ha of cropland in the USA, this translates to a potential reduction in carbon emissions of 4.3 million metric tonnes carbon equivalent (MMTCE)/year.

These results further support the energy efficiencies and benefits of no-tillage. Conversion of ploughed tillage to no-tillage, using integrated nutrient management and pest management practices, and enhancing water use efficiency can save carbon emissions and at the same time increase the soil carbon pool. Thus, adopting conservation agriculture techniques is a holistic approach to management of soil and water resources. Conservation agriculture improves efficiency and enhances productivity per unit of carbon-based energy consumed and is a sustainable strategy.

## Carbon Emissions and Sequestration

Tillage or soil preparation has been an integral part of traditional agricultural production. Tillage fragments the soil, triggers the release of soil nutrients for crop growth, kills weeds and modifies the circulation of water and air within the soil. Intensive tillage accelerates soil carbon loss and greenhouse gas emissions, which have an impact on environmental quality.

By minimizing soil tillage and its associated ($CO_2$) emissions, global increases of atmospheric carbon dioxide can be reduced while at the same time increasing soil carbon deposits (sequestration) and enhancing soil quality. The best soil management systems involve minimal soil disturbance and focus on residue management appropriate

and methods for optimum application of conservation agriculture.

Since $CO_2$ is the final decomposition product of SOM, intensive tillage, particularly the mouldboard plough, releases large amounts of $CO_2$ as a result of physical disruption and enhanced biological oxidation (Reicosky *et al.*, 1995). With conservation tillage, crop residues are left more naturally on the surface to protect the soil and control the conversion of plant carbon to SOM and humus. Intensive tillage releases soil carbon to the atmosphere as $CO_2$, where it can combine with other gases to contribute to the greenhouse effect.

Soils store carbon for long periods of time as stable organic matter. Natural systems reach an equilibrium carbon level determined by climate, soil texture and vegetation. When native soils are disturbed by agricultural tillage, fallow or residue burning, large amounts of carbon are oxidized and released as $CO_2$ (Allmaras *et al.*, 2000). Duxbury *et al.* (1993) estimated that agriculture has contributed 25% of the historical human-made emissions of $CO_2$ during the past two centuries. However, a significant portion of this carbon can be stored, or sequestered, by soils managed with no-tillage and other low-disturbance techniques. Increased plant production greater than that of native soil levels by the addition of fertilizers or irrigation can enhance carbon sequestration.

Carbon is a valuable environmental natural resource throughout the world's industrial applications of production and fossil energy consumption. Releasing carbon to the atmosphere by energy processes may be offset by capturing carbon with plant biomass and subsequently soil carbon sequestration in the form of organic matter. Energy consumers may at some time be required to compensate for their atmospheric carbon emissions by contracting with those who can sequester atmospheric carbon. Constage, it provides an important potential benefit.

A more detailed explanation of carbon dioxide emissions and sequestration is given in Chapter 17, together with comments on how these interact with nitrous oxide and methane emissions and the potential for carbon trading.

## Summary of the Benefits of No-tillage

Conservation tillage, and particularly no-tillage, agriculture has universal appeal because of numerous benefits. Improved production with fewer inputs and reduced time and energy are often cited as the highlights. Conservation agriculture techniques benefit the farmers and the whole of society, and can be viewed as both 'feeding and greening the world' for global sustainability. Agricultural policies are needed to encourage farmers to improve soil quality by storing carbon as SOM, which will also lead to enhanced air quality, water quality and productivity and help to mitigate the greenhouse effect.

Some of the more important benefits of conservation tillage farming are:

1. Improved crop production economics.
2. Increased SOM.
3. Improved soil quality.
4. Reduced labour requirements.
5. Reduced machinery costs.
6. Reduced fossil-fuel inputs.
7. Less runoff and increased available plant water.
8. Reduced soil erosion.
9. Increased available plant nutrients.
10. Improved global environment.