Chapter 22
Conservation Agriculture and Climate Change

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Abstract This chapter review aims at developing a clear understanding of the impacts and benefits of conservation agriculture (CA) with respect to climate change, and examining if there are any misleading findings at present in the scientific literature. Most of the world's agricultural soils have been depleted of organic matter and soil health over the years under tillage-based agriculture (TA), compared with their state under natural vegetation. This degradation process can be reversed and this chapter identifies the conditions that can lead to increase in soil organic matter content and improvement in soil health under CA practices which involve minimum soil disturbance, maintenance of soil cover, and crop diversity. The chapter also discusses the need to refer to specific carbon pools when addressing carbon sequestration, as each carbon category has a different turnover rate. With respect to greenhouse gas emissions, sustainable agricultural systems based on CA principles are described which result in lower emissions from farm operations as well as from machinery manufacturing processes, and that also help to reduce fertilizer use. This chapter describes that terrestrial carbon sequestration efficiently be achieved by changing the management of agricultural lands from high soil disturbance, as TA practices to low disturbance, as CA practices, and by adopting effective nitrogen management practices to provide a positive nitrogen balance for carbon sequestration. However, full advantages of CA in terms of carbon sequestration can usually be observed only in the medium to longer term when CA practices and associated carbon sequestration processes in the soil are well established.

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22.1 Introduction

Agronomy management in agricultural landscapes should deploy production practices in harmony with soil-mediated ecosystem functions in order to deliver a broad range of ecosystem services (Kassam et al. 2013). Conventional agriculture is tillage-based in industrialized as well as developing countries and relies, as a key operation for seedbed preparation, on mechanical soil tillage with no organic mulch cover. It is generally considered to speed up the loss of soil organic matter (SOM) by increasing its mineralization and through soil loss by erosion. In addition, tillage is a high energy-consuming operation that uses large amounts of fossil fuel per hectare in mechanized systems. In contrast, conservation agriculture (CA) is an agroecological approach to resource-conserving agricultural production that complies with three practical principles, namely (1) minimum mechanical soil disturbance (with no-till and direct seeding), (2) maintenance of permanent organic soil cover (with crops, cover crops, and/or crop residues), and (3) species diversification through crop rotation and association (involving annual and/or perennial crops including tree and pasture crops) FAO (2012). CA facilitates good agronomy such as timely operations, improves overall land husbandry for rainfed and irrigated production, and is complemented by other good practices such as the use of quality seeds and integrated pest management (Pisante et al. 2012).

Anthropogenic climate change (i.e., that resulting from human activities) is probably the most serious environmental challenge facing us today. Human activities contribute significantly to increased concentrations of atmospheric greenhouse gases (GHGs), which in turn alter the way in which thermal radiation is absorbed by the planet and reradiated, changing global temperatures, and climatic patterns. As a consequence, we are faced with two parallel imperatives in order to deal with what could be a very damaging situation:

- Climate change adaptation: we must make changes to the way we do things to ensure that the ecosystem services upon which we rely on are sustained as conditions change.
- Climate change mitigation: the emission of GHGs must be reduced and the sequestration of atmospheric carbon increased (removal from the atmosphere to soil and vegetative stores).

The combined environmental benefits of CA at the farm and landscape level can contribute to global environmental conservation and provide a low-cost option to help offset emissions of the main GHGs. This chapter tackles CA and climate change as well as what solutions are being implemented in different parts of the world for an efficiently sustainable farming and landscape management.

22.2 CA and Climate Change

22.2.1 Impacts of Climate Change

The conclusions of the recent Working Group I contribution to the AR5-IPCC (IPCC 2013) confirmed that human activity has played a primary role in the observed global warming since the mid-nineteenth century, and indicated that future increases in GHG concentration may further increase global mean surface temperature and amplify changes in precipitation patterns and amounts. Proof of these changes has been widely observed through several instrumental data on both local and global scales. According to the latest IPCC report (IPCC 2013), the globally averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of 0.85 °C from 1880 to 2012. This increase was observed mostly since 1950.

Moreover, on a global scale, several changes in the frequency and intensity of daily temperature extremes have been observed since the mid-twentieth century. In particular, averaged maximum and minimum temperatures over land have both increased by in excess of 0.1 °C per decade. Significant multi-decadal variability was highlighted, including a recent period (1997–2004) of no change. In addition, a significant increase in daily minimum temperature rather than maximum has been observed (Alexander et al. 2006; IPCC 2013).

Global mean precipitation has increased annually by about 2 % from 1900 to 1998 (Dai et al. 1997; Hulme et al. 1998) which corresponds to approximately 1.1 mm per decade (IPCC 2007). The precipitation trend varied worldwide, with higher increases in specific areas (from + 7 to + 12 %, between 30 and 85°N) and less in others (+ 2 % between 0 and 55°S; IPCC 2007). In addition, a considerable decrease in snowfall events has occurred. In particular *in situ* observations showed significant reductions in the extent of snow cover over the past 90 years particularly in June, when the average extent of snow cover decreased by 53 % (40–66 %) from 1967 to 2012 (IPCC 2013).

Recent years have been also characterized by a large number of extreme episodes as heat waves, cold spells, and floods. Globally, while cold spells decreased, heat waves significantly increased (Alexander et al. 2006). In particular, a significant reduction in cold spells was observed over central and northern Russia, parts of China and northern Canada, while warm spells increased over central and eastern USA, Canada, and parts of Europe and Russia (Alexander et al. 2006).

Looking at climate projections, simulations developed for IPCC's Fifth Assessment Report (AR5) projected increases in mean surface temperature for the end of the twenty-first century is likely to exceed 1.5 °C relative to 1850–1900. More specifically, this projected increase is likely to range from 0.3 to 4.8 °C depending on the new Representative Concentration Pathways (RCPs) scenarios. However, warming above 4 °C by 2081–2100 is unlikely in almost all RCPs scenarios. It is also virtually certain that many areas will be characterized by an increase in hot temperature extremes and a decrease in cold temperature extremes as global mean temperatures increase.

The AR5 also confirmed an increase in global mean precipitation with increasing global mean surface temperature. According to the four RCPs scenarios, this increase is likely to range from 0.5 to 4 % $°C^{-1}$ at the end of the twenty-first century. Generally, the pattern of change indicates that high latitudes and moist midlatitude regions are likely to experience more precipitation. Conversely, many midlatitude and subtropical arid and semiarid regions are likely to experience less precipitation by the end of this century. The latest IPCC report (IPCC 2013) also indicated an increase in extreme precipitation events in terms of intensity and frequency, especially over most midlatitudes and wet tropical regions.

These changes in climate regimes may have severe consequences especially in sectors like agriculture, where the lifecycle of crops is mainly determined by climate conditions. Therefore, changes in temperature and precipitation trends can bring shifts in phenology, yield changes, modification of crop physiology, and resilience (Parmesan 2006; IPCC 2007; Cleland et al. 2007; Zhao and Running 2010, Olesen et al. 2011).

Expected increases in temperature can lead to positive or negative impacts on crop growth and yield depending on several factors (i.e., region, crop type, etc.). Generally, at high and middle latitudes, global warming is expected to increase the length of the growing season especially with the advance of spring sowing. The lengthening of the growing season is expected to increase crop growth and productivity, thus resulting in higher crop yields (Easterling and Apps 2005). In particular, for countries at latitudes > 60°N, advances in sowing time are estimated to proceed very rapidly (Peltonen-Sainio et al. 2009; Rötter et al. 2011). Similarly, Olesen et al. (2012) indicated an advance of spring cereal sowing from 1 to 3 weeks by 2040. Moreover, warmer climate conditions are expected to increase potential cultivated areas of commonly grown major and/or minor crops, especially above their current northern limits for cultivation (Peltonen-Sainio et al. 2009). In particular, crops with higher thermal need (e.g., soybean and sunflower) are expected to move towards northern areas (Harrison et al. 1995; Bindi et al. 1996; Moriondo et al. 2010; Bindi and Olesen 2011). These crops, however, may encounter some limitations when adapting their photoperiod to different summer light conditions. Conversely, warmer conditions may be detrimental for crop growth and productivity over southern regions. In these areas, the temperature increase may result in faster physiological development, thus shortening the growing season and consequently the time for biomass accumulation (e.g. Lobell and Field 2007; Battisti and Naylor 2009; Giannakopoulos et al. 2009; Supit et al. 2010; Confalonieri et al. 2012).

The negative effect of higher temperatures on crop growth and productivity may be counterbalanced by the higher atmospheric CO_2 concentration, which is expected to increase crop productivity through a higher photosynthetic rate (Kimball et al. 2002; Ainsworth and Long 2005; Qaderi and Reid 2005; Franzaring et al. 2008). The benefit of higher CO_2 concentration is mainly expected for C3 species (i.e., almost all cereals and legumes, etc.), compared with C4 species (e.g., maize, sorghum, sugarcane, etc.; Kimball et al. 2002; Ainsworth and Long 2005; Southworth et al. 2000; Yano et al. 2007). Elevated atmospheric CO_2 concentrations are expected to reduce the vulnerability of pasture and forage production to climate variability and increase crop roots yields (Farrar 1996; Soussana and Lüschert 2007).

Nevertheless, increases in CO_2 may be insufficient to completely recover yield losses due to higher temperatures. Tubiello et al. (2007) suggested that in the most vulnerable areas such as the Mediterranean basin the benefit offered by higher CO_2 concentration might be nullified if temperatures increase by about 2 °C.

Besides temperature and the CO_2 concentration, crop growth and productivity are also determined by water availability; therefore, changes in precipitation trends (total amount, frequency, and intensity) are expected to have devastating effects on agricultural systems in many regions. For instance, in the Mediterranean basin, the expected decrease in precipitation by up to 20 % (Del Río et al. 2011) coupled with increased rainfall frequency and intensity may lead to prolonged water deficit. This condition may be extremely harmful during the most sensitive growth phases (i.e., flowering, pollination, and grain filling), especially if coupled with the expected increase in evaporation rate, which can lead to negative consequences such as the complete failure of potential yield. Furthermore, crop systems may suffer higher competition with other plants (i.e., weeds, trees, etc.) for freshwater availability, while the expected increase in evaporation rate will also contribute to increased soil salinization risk, preventing cultivation of highly sensitive crops (e.g., vegetables, fodder, root, and tuber crops).

Finally, further increases in extreme events (i.e., drought and heat stress) are expected to be detrimental for cropping systems. Drought affects yields by reducing grain number and the amount of dry matter produced during flowering, or decreasing grain number and size through the reduction and limitation of ovule function and nutrient supply during the reproductive stage (Wheeler et al. 1996; Prasad and Staggenborg 2008). Conversely, heat stress influences seed-filling duration, resulting in smaller seeds and lower yields (Prasad and Staggenborg 2008). Although these events can occur independently, their combined impact are the most detrimental for crop systems affecting almost all plant physiological processes (i.e., growth, productivity, area expansion, number and final size of leaves, photosynthesis, etc.; Jagtap et al. 1998; Jiang and Huang 2001; Alves and Setter 2004; Rizhsky et al. 2004; Prasad et al. 2006a, b). These observed and predicted changes in climate and, in turn, crop systems have raised further concern about how to reduce, or at least limit, further impacts over the next decades (IPCC 2007). In order to deal with the evolution of these changes, adaptation and mitigation strategies may be applied.

Adaptation strategies are aimed at minimizing the consequences of climate change and variability on crop systems. These strategies tackle the effects of climate change through policies, planning, and measures that are efficient in the short term by maintaining suitable yields. Adaptation options need both global and local coordination; however, they can be independently developed and applied by individual farmers.

Conversely, mitigation strategies aim to reduce or stabilize GHG emissions from anthropogenic activities. They constitute an economic benefit by reducing the impacts of climate change and its consequent costs. These strategies deal with the causes of climate change through a long-term activity, which should be coordinated at a global scale and involve several countries and institutions. Among the agricultural adaptation and mitigation strategies that can be combined to reduce climate change impacts, CA may represent a good option to obtain sustainable crop production and cope with climate change.

22.2.2 Adaptation

CA systems tend to offer more climate change adaptation benefits than conventional farming systems. Most of these benefits are related to increasing both soil fertility and water conservation. The application of CA principles should produce changes in soil properties and physical, chemical, and biological processes, thus enhancing water supply and soil quality (Palm et al. 2013). These improvements are fundamental for minimizing yield variability and maintaining suitable productivity, especially under climate change conditions.

According to several studies (Stockfisch et al. 1999; Tebrügge and Düring 1999; Horáček et al. 2001), both reduced tillage (RT) and no-tillage (NT)—by modifying biological activity, topsoil physical properties, and soil erosion (Dennis et al. 1994; Balabane et al. 2005; Riley et al. 2005)—allow considerable accumulation of SOM on topsoil as well as carbon vertical stratification (Hernanz et al. 2002; Moreno et al. 2006), thus resulting in improved soil fertility and, in turn, higher productivity. Moreover, RT and NT can also contribute to reduce soil erosion that is widely accepted as detrimental for crop productivity. According to Tebrügge and Düring (1999) and Hernanz et al. (2002), these practices can improve the stability of soil aggregates and avoid soil surface sealing. This change in soil structure improves soil fertility and, as a consequence, the crop's productivity efficiency.

Permanent soil organic cover is another main principle of CA. While RT and NT can limit water infiltration in soil due to surface crust formation, the presence of residues on the soil surface can increase water storage (Lampurlanés and Cantero-Martínez 2006). Moreover, cover crops can also avoid runoff by reducing the overland flow velocity, thus improving soil structure (Sudhishri et al. 2008; Dass et al. 2010). The improved soil structure and increased water availability is mainly due to the increased bio-pores, which should maximize the effect of rainfall and recharge groundwater, and therefore reducing the impacts of drought (Wuest 2001; Herrero et al. 2001; Akbolat et al. 2009; Ben Moussa-Machraoui et al. 2010). Therefore, permanent soil organic cover is a fundamental strategy for limiting expected yield losses under climate change, especially in dry areas.

Despite the role of cover crops being considered fundamental for erosion mitigation, many studies (Friebe and Henke 1991; Puget et al. 1995; Frielinghaus 2002; Balabane et al. 2005) concur that there are even further benefits when soil cover is coupled with RT or NT. This combination may increase aggregate stability and soil water infiltration rate, which are closely linked to SOM, soil organic carbon (SOC), and earthworm activity. Therefore, the coupling between soil cover and RT or NT is expected to be fundamental, especially over those regions where climate change results to be very detrimental for crop growth. In particular, for Mediterranean areas, several studies on annual and perennial crops suggested that the combined effect of minimum soil disturbance and soil cover seems to reduce both water and wind erosion but also increase precipitation storage (De Alba et al. 2001; López et al. 2001; Gómez et al. 2005; López and Arrúe 2005; De la Rosa et al. 2005; Cantero-Martinez et al. 2007).

Even diversification of crop species and rotations may be functional as adaptation strategies to cope with climate change. In particular, the role of legumes is expected to gain more importance due to the biological nitrogen fixation process, an efficient way to supply large amounts of nitrogen to the soil and to build SOM.

22.2.3 Mitigation

According to several studies (i.e., Lal et al. 2007; FAO 2011; Kassam et al. 2009), the application of CA over wide areas may have the potential to slow/reverse the rate of emissions and enhance the sinks of CO_2 and other GHG by agriculture. This was confirmed by Smith and Olesen (2010) who found that the proper application of the main CA pillars can contribute to reduce GHG emissions particularly through improved nitrogen use efficiencies and enhanced soil carbon storage. In particular, a study carried out by Baker et al. (2007) estimated that the global conversion of all croplands to conservation tillage could sequester 25 Gt C over the next 50 years.

In regard to minimum soil disturbances (i.e., RT and NT), both practices can contribute to reducing GHG emissions by reducing SOM oxidation into CO_2, which increases under conventional tillage (FAO 2011). However, the C sink response varies under both RT and NT depending on the area considered (Eagle et al. 2011). RT and NT can increase soil C sequestration by improving whole soil structure. In particular, increasing the number and quality of soil aggregates coupled with less soil compaction reduces CO_2 losses from soil, thus enhancing the passive C pools in soil. Moreover, as an indirect consequence especially of NT, a strong reduction in CO_2 emissions can result from lower fuel energy inputs due to less machinery use (FAO 2008).

In addition, permanent soil organic cover is useful for increasing long-term carbon sequestration processes (West and Post 2002). Improved soil structure will contribute to reduced CO_2 fluxes from soil. For instance, soil organic cover can reduce the risk of erosion episodes and limit C losses for soil respiration through the reduction of the impact of rain drops with high energy during intense rainfall events. Soil C storage can increase due to the presence of abundant root biomass. This was confirmed by Kassam et al. (2009) who identified roots as the main source of CO_2 sequestration due to their capacity to partially stock C above- and belowground as a resistant SOM pool.

Permanent soil organic cover can also limit GHG emissions indirectly. First, it can decrease CO_2 emissions through increased inter-species competition. This reduces the presence of invasive species and, in turn, CO_2 emissions due to less use of machinery for weed treatments. Second, permanent soil organic cover helps maintain high nitrogen levels close to roots, thus lower fertilization requirements and, in turn, N emissions.

Finally, the diversification of crop species and rotation should enhance SOC concentration in soil (Gregorich et al. 2001), especially when the soil nitrogen balance is positive (Bayer et al. 2000a, b). In this context, the ability of legumes to provide sufficient N supply can increase C stock in soil, thus increasing atmospheric C sequestration. The role of mineral N as fertilizer in SOC improvement was confirmed in several studies (Mrabet et al. 2001; Baker et al. 2007; Mrabet 2008; López-Fando et al. 2007; Akbolat et al. 2009; López-Bellido et al. 2010). In addition, legumes increase soil N content, thus reducing the need to apply energy inputs such as fertilizer.

22.3 CA for Carbon Storage in Cropland

22.3.1 SOC Accumulation

SOC constitutes on average about 58 % SOM. Several SOM pools can be distinguished in the soil on the basis of size, state of decomposition, and chemical and physical properties. A labile pool, also known as the active pool, is the least decomposed organic matter smaller than 2 mm but larger than 0.25 mm. It consists mainly of young SOM (such as plant debris), is partially protected in macroaggregates, characterized by a rapid turnover or transformation, sensitive to land and soil management and environmental conditions. It consequently plays an important role in short-term carbon and nitrogen cycling in terrestrial ecosystems and can be used as a sensitive indicator of short- and medium-term changes in soil carbon in response to management practices (Chan 1997; Whitbread et al. 1998).

The pool of SOM, smaller than 0.25 mm and larger than 0.053 mm (250–253 μm), is a labile, insoluble intermediate in the SOM continuum from fresh organic materials to humified SOC, ranging from recently added plant and animal debris to partially decomposed organic material. The stable pool, the recalcitrant SOM, contains particles less than 0.053 mm (< 53 μm). The organic matter has reached the highest level of transformation and is incorporated into aggregates, where its further decomposition is protected. It holds moisture, retains cations for plant use, and acts as a recalcitrant binding agent preventing nutrients and soil components from being lost through leaching.

Several factors which determine the soil carbon budget are influenced by land management practices; in this context, the reasons for the positive influence of CA in SOC accumulation is related to the permanent and total protection of the soil through species diversity, a similar pattern to that of the most stable natural ecosystems. These conditions are inherent in CA principles, i.e., minimum mechanical soil disturbance, permanent soil organic cover, and species diversification. The permanent presence of abundant, undisturbed (above- and belowground) biomass fosters the buildup of new SOC (Stagnari et al. 2009) and carbon losses from decomposition are reduced by SOC inclusion within soil aggregates, as enhanced by the low soil disturbance (Table 22.1; de Moraes Sà et al. 2001).

With respect to the first principle of CA, SOC accumulation is a reversible process and any short-term disturbance, in a system which aims to improve carbon

Table 22.1 SOC accumulation in deeper soil layers under the CA management system

Location	Experiment duration	Results	Author
USA, north	22 years	The carbon stock under CA to a depth of 122 cm is 10.6 t ha^{-1} greater than that under TA	Doran et al. 1998
Brazil, south	13 years	Where complex rotations are adopted, soil carbon stocks under CA are approximately 17 t ha^{-1} higher than under TA, and that 46–68 % of carbon gains occurs at 30–85 cm depth	Sisti et al. 2004
Brazil, south	17 years	Samplings to 107.5 cm depth in an Acrisol demonstrate the significant potential of legume crops and nitrogen fertilization under CA to improve SOC stocks: the average carbon sequestration rate of legume-based cropping systems (with N-fertilizer) in the whole 0–107.5 cm layer was 1.42 t ha^{-1} y^{-1} when considering the soil profile down to 100 cm depth	Diekow et al. 2005
Brazil, south	15–26 years	The experiments on free-draining Ferralsols under rotations containing intercropped or cover-crop legumes show annual SOC accumulation rates of between 0.04 and 0.88 t ha^{-1} to 30 cm and from 0.48 to 1.53 t ha^{-1} y^{-1} when considering the soil profile down to 100 cm depth	Boddey et al. 2009
Brazil, south	13 years	When green-manure cover crops are part of the rotation soil carbon stocks were approximately 17 t ha^{-1} higher under CA than under TA	Sisti et al. 2004
USA, Indiana	28 years	10 t ha^{-1} greater SOC content under CA than in moldboard plowed trials at 0–100 cm depth in a dark-colored Chalmers silty clay loam in Indiana	Gál et al. 2007
Australia		Higher SOC cncentrations at 230 cm depth in Vertisols when compared with other soil types in Australia	Knowles and Singh 2003

CA conservation agriculture, *TA* tillage-based agriculture, *SOC* soil organic carbon

status as a long-term management tool, will not achieve significant improvement in SOC accrual (Jarecki and Lal 2003; Al-Kaisi 2008). The formation of stable microaggregates within macroaggregates is inhibited under tillage-based agriculture (TA; Six et al. 1998). Even with a single tillage event, sequestered soil carbon and years of soil restoration may be lost, and the damage to soil life is considerable (Grandy et al. 2006). In general, the mixing of litter in tilled soils favors bacteria (hence quick degradation processes), while the higher presence of fungi in undisturbed systems like CA (Beare et al. 1992, 1993; Frey et al. 1999; Guggenberger et al. 1999; Drijber et al. 2000) is responsible for a buildup of soil carbon in the form of polymers of

Table 22.2 Percentage of carbon in the crop residues released from the soil after different treatments (Reicosky 1997)

Tillage practice	Percentage of carbon in the crop residues released as CO_2
Moldboard plow	134
Moldboard plow and disc harrow	70
Disc harrow	58
Chisel plow	54
Sod seeding	27

Table 22.3 Carbon costs of the variables that intervene in the CA and the TA systems. (Smith et al. 1998; Tebrügge 2000; FAO 2001, 2008, 2009)

Variables	Cost of the variable under CA as compared to TA
Fuel consumption per unit area output	35–80 % less
Number of passes	50–54 % less
Size of machinery	50 % lower power requirement
Depreciation rate of machinery	Two to three times lower (i.e., two to three times longer lifetime)

melanin and chitin, which are relatively stable and resist degradation (Stahl et al. 1999; Bailey et al. 2002). Beyond its effect on the oxidative breakdown of SOM through mineralization, tillage has a direct effect on CO_2 exchange between the soil and atmosphere. The amount of CO_2 lost is directly correlated to the disturbed soil volume; consequently plowing, by disturbing the greatest soil volume, produces the maximum CO_2 flux, while NT causes the least CO_2 loss (Reicosky and Lindstrom 1993, Reicosky et al. 1995; Reicosky 1997, 1998; Table 22.2). In addition, plowing is an energy-intensive process: On average, tillage agriculture uses up to 80 % more energy (fuels) than CA (Table 22.3). Studies have also identified tillage-induced soil erosion as the major cause of severe soil carbon loss and soil translocation on convex upper slope positions of cultivated, upland landscapes (Lobb et al. 1995; Lobb and Lindstrom 1999; Reicosky et al. 2005).

The amount of SOC is limited by the availability of sufficient plant residue. In conventional agricultural systems, aboveground production is removed (harvested or used as livestock feed) or burned, leaving only root biomass for incorporation into SOM. Sometimes above- and belowground inputs are mechanically mixed (e.g., by disking or chiseling) into the soil with the residues rapidly decaying (Magdoff and Weil 2004). Such decay of SOM depends on the composition of the material: Readily decomposable carbon (e.g., low C/N ratio residues or liquid manure) generally induces a priming effect and increases CO_2 emissions. The composition of residues not mixed into the soil does not affect the decay of accumulated SOM (Chadwick et al. 1998; Flessa and Beese 2000; Kuzyakov et al. 2000; Chantigny et al. 2001; Bol et al. 2003; Fontaine et al. 2004; Sisti et al. 2004; Fontaine 2007). In no-tilled soils over long periods, SOM decomposition on the soil surface is reduced and increasing active fractions of SOM are observed (Franzluebbers et al. 1995a, b; Stockfisch et al. 1999; Tebrügge and During 1999; Horáček et al. 2001). The accumulation of SOM in surface layers influences carbon vertical stratification (Hernanz et al. 2002; Moreno et al. 2006), water infiltration, erosion resistance, and nutrient availability.

There is also clear evidence that species diversification, the third pillar of CA, positively influences SOC storage. Indeed, some authors found negative SOC accumulation rates under repeated monocropping in conventional systems (Angers et al. 1997; Wanniarachchi et al. 1999, VandenBygaart et al. 2003). Changing from monocropping to a multicrop rotation positively influences SOC concentration. Several studies comparing SOC concentration under multicropping with monocropping systems support this theory (Havlin et al. 1990; Entry et al. 1996; Mitchell et al. 1996; Robertson et al. 1994; Robinson et al. 1996; Buyanovsky and Wagner 1998; Gregorich et al. 2001; Lopez-Fando and Pardo 2001). In addition, soil type and climatic conditions are important variables which can strongly modify the effects of cropping pattern on SOC (VandenBygaart et al. 2003). Each type of rotation has a different potential to induce carbon sequestration. Generally, carbon accumulates when the nitrogen balance of the crop rotation is positive (Sidiras and Pavan 1985; Bayer and Mielniczuck 1997; Boddey et al. 1997; Alves et al. 2002, 2003, 2006; Sisti et al. 2004; Bayer and Bertol 1999; de Maria et al. 1999; Amado et al. 1999, 2001; Bayer et al. 2000a, b). Negative SOC accumulation rates under CA are associated with specific rotations, i.e., with fallow-, barley- and soybean-based rotations. In any case, fallow-based rotations should not be associated with the concept of CA (Black and Tanaka 1997; VandenBygaart et al. 2003; Hernanz et al. 2009; López-Bellido et al. 2010). A barley–wheat–soybean rotation does not seem to allow SOC accumulation (Angers et al. 1997). Barley, as a versatile species, is often cultivated, where growing conditions (e.g., climate and soil fertility) are most difficult for cereal crops as well as for SOC accumulation. Further negative SOC accumulation rates under CA were observed in a maize–wheat–soybean rotation (Yang and Kay 2001; VandenBygaart et al. 2002). Including soybean in the rotation does not appear sufficient to enhance SOC accumulation: Most of the fixed nitrogen was exported with the grain (Sisti et al. 2004) and, while its residues may improve nitrogen availability, they decomposed very quickly, returning insufficient biomass to the soil.

Agricultural systems such as CA that rely on permanent organic soil cover and NT to maintain crop residues on the surface layer lead to superficial SOC accumulation, and offer potential benefits in controlling some negative environmental effects traditionally associated with agroecosystems.

22.3.2 Soil Biodiversity

The positive impact of CA is not restricted to SOC accumulation, but more generally it induces enhancements in terms of soil quality, i.e., the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, to maintain environmental quality, and to promote plant and animal health (Doran and Parkin

1994). One fundamental aspect of soil quality is "biodiversity," which had not been appropriately considered until some years ago. Soil biodiversity is normally described as the variability of living forms—soil fauna, flora, vertebrates, birds, and mammals—within a habitat or management system of a territory involved in agricultural activity.

It has been largely demonstrated that in undisturbed soil or soil managed following CA techniques, biomass diversity and biological activity are higher compared to those under deep cultivation (Lupwayi et al. 2001; Spedding et al. 2004). Bacteria, actinomycetes, fungi, earthworms, and nematodes are higher in mulched fields than in those where residues are incorporated. The rate of organic C input from plant biomass is generally considered the dominant factor controlling the amount of microbial biomass in soils (Campbell et al. 1997); as the total organic C pool expands or contracts, the microbial pool also expands or contracts (Franzluebbers et al. 1999).

Microfauna, such as protozoa (Cochran et al. 1994), are favored by those management practices that are expected to also favor bacteria, since bacteria are their main food source. In addition, the abundance of mesofauna, in particular potworm, is greater where CA is practiced than in compacted soil (Röhrig et al. 1998). The negative effects on microarthropod populations are caused in part by the physical disturbance of the soil by tillage. Some individuals may be killed initially by abrasion during tillage operation or being trapped in soil clods after tillage inversion (Wardle 1995).

Soil mesofauna are mainly represented by springtails (Collembola) and mites (Acari; Kladivko 2001). Springtails are usually inhibited by tillage disturbances (Miyazawa et al. 2002; Wardle 1995). Mites exhibit more extreme responses to tillage than microbial groups: moderate to extreme increases or decreases have been observed (Wardle 1995). Interestingly, the mite population seems more affected by cover crop than tillage practice (Reeleder et al. 2006). Another important mesofauna group is the enchytraeids, thanks to their burrow which increases aeration, water infiltration, and root growth (Cochran et al. 1994). They may be inhibited or apparently stimulated by tillage in contrast with most other groups, probably due to their ability to recover from disturbances (Wardle 1995).

Large organisms (macrofauna) appear to be especially sensitive to agroecosystem management (Chan 2001; Folgarait 1998; Black and Okwakol 1997; Kladivko et al. 1997; Robertson et al. 1994; Holt et al. 1993; Barnes and Ellis 1979) with less negative impacts on species with high mobility and higher population growth potential (Decaëns and Jiménez 2002). Earthworms play a crucial role in mixing plant residues and other materials into the soil, particularly important in no-till systems due to the lack of mechanical mixing (House and Parmelee 1985). Earthworm species differ in their ecological behavior thus having different effects on soils. Large earthworms produce large-sized and compact aggregates, whereas small eudrilid earthworms produce small, fragile castings; both groups appear essential for maintaining soil structure (Blanchart et al. 2004). Their abundance, diversity, and activity increase under CA when compared to conventional agriculture (Kladivko 2001; Chan 2001; Kladivko et al. 1997; Barnes and Ellis 1979; Gerard and Hay 1979; Table 22.4). The few exceptions (Nuutinen 1992; Wyss and Glasstetter 1992)

Table 22.4 Abundance of earthworms (number m^{-2}) under no-tillage, conventional tillage, and permanent pasture

No-tillage	Conventional tillage	Permanent pasture	Remarks	Reference
270	90	–	On a very poorly drained soil, cultivation by normal plowing	Boone et al. 1976
137	67	–	Cultivation by deep plowing	Gerard and Hay 1979
913	213	–	Cultivation involved moldboard plowing, three disk plowing and two rotary tilling	House and Parmelee 1985
342	130	–	Lupin/wheat rotation, three cultivation to 7 cm with a duck food scarifier	Rovira et al. 1987
275	117	–	Cultivation involved scarifying (10 cm) two to three times and light harrowing (7 cm)	Haines and Uren 1990
266	48	477	–	Deibert et al. 1991
467	52	1017	–	Springett 1992
250	175	825	Lismore site, after 8 years of cropping	Francis and Knight 1993
–	52	168	–	Mele and Carter 1999

are probably related to type and timing of tillage as well as original species assemblage (Chan 2001). Tillage is the main factor perturbing earthworm populations, but mulched crop residues are fundamental, since earthworms are unable to maintain a constant water content (Edwards and Bohlen 1996).

Although ants are as important as earthworms in soil transformation, there is a lack of literature on ants in agroecosystems (Gotwald 1986). In general, ants increase infiltration by improving soil aggregation and porosity (Nkem et al. 2000) even in situations of low organic matter and clay contents (Mando and Miedema 1997). Management options favoring ant populations, such as residue mulch and reduced or zero tillage, have been identified as key factors in improving topsoil in agroecosystems, even in the degraded conditions of the Sahel (Mando and Miedema 1997). Most arthropods concentrate their activities above or within the topsoil and take part, at least partially, in organic matter incorporation through burrowing and food relocation (Zunino 1991). Theoretically, arthropods (Coleoptera and Araneae) favor CA conditions given the litter presence on the soil surface, which constitutes a food source for many arthropods (Kladivko 2001), and the higher niche availability (Ferguson and McPherson 1985). Nevertheless, many studies conducted in North America and Europe report inconsistent results with increased (Andersen 1999; Holland and Reynolds 2003), decreased (Andersen 1999; Holland and Reynolds 2003) or no effect (Holland and Reynolds 2003) on arthropod abundance. Generally, species diversity of all arthropod guilds is higher in CA compared to conventional agriculture (Stinner and House 1990). Interestingly, various authors (Holland and

Reynolds 2003; Marasas et al. 2001; Stinner and House 1990; House and Stinner 1983) found an increased presence of predators (spiders as well as carabid and staphylinids beetles) compared to phytophagous species under zero tillage systems.

22.3.3 Soil Moisture

Eighty percent of the world's cultivated land depends on "green water" for its production, which is defined as water located in the soil. Agriculture which depends only on green water is called "rainfed agriculture." Green water resources will, in the foreseeable future, be the dominant source for human food production. However, only 15 % of actual rainfall is productively used for crop growth, while the pressure on "blue water resources" is increased. The ground water, or surface water bodies, is limited; consequently, it will be difficult to increase the size of areas under irrigation. More pragmatically, it would be necessary to increase the efficiency of green water resources.

Improves soil and water management is possible through CA; data indicate increased crop yields of 10–100 % with water requirements for crop production reduced from 2500 to 1250 m^3 ton^{-1}. Conversely, conventional farming favors the loss of soil moisture by reducing the ability of the soil to capture, drain, and store rainwater. Unproductive losses take place through surface runoff, unproductive soil evaporation in bare soil surfaces, and unproductive evaporation due to soil aeration during tillage operations. There is evidence that long-term use of conventional tillage leads to soil compaction, increased runoff, and poor infiltration (Hussain et al. 1999b; Ferreras et al. 2000), ultimately determining the risk of soil erosion. Indeed, the destruction of the original soil structure alters many soil physical proprieties including the stability of aggregates > 2 mm (Chan et al. 2001), pore space and size distribution, water-holding capacity, and soil water content. CA, which favors improved soil structure and continuous soil pores, enables higher infiltration and ultimately increases available water for crop production (Roth et al. 1988; Thierfelder et al. 2005). Azooz and Arshad (1996) found that both saturated and unsaturated hydraulic conductivities were higher under zero tillage conditions than under conventional tillage on two luvisols (silty loam and sandy loam soils). Chan and Heenan (1993) found that, despite similar bulk densities, hydraulic conductivity under ponded infiltration of zero tillage with residue retention was one to four times that of conventional tillage with residues burnt. In the USA, CA reduced runoff by between 15 and 89 % and reduced dissolved pesticides, nutrients, and sediments within it (Clausen et al. 1996). Besides lower runoff intensity, numerous studies have shown significant reductions in soil erosion rates with CA or NT (Govaerts et al. 2007; Li et al. 2007; Pinheiro et al. 2004; Chan et al. 2002; Filho et al. 2002).

The effects of CA on soil evaporation are significant. Tillage moves moist soil to the surface, increasing drying losses (Hatfield et al. 2001). It has been demonstrated that tillage disturbance of the soil surface increases soil water evaporation more than untilled areas (Blevins et al. 1977; Papendick et al. 1973). The amount of energy the soil surface receives is influenced by canopy and residue cover. Greb (1966) found that residue and mulches reduce soil water evaporation by reducing soil temperature, impeding vapor diffusion, absorbing water vapor into mulch tissue, and reducing the wind speed gradient at the soil–atmosphere interface; residue thickness (volume) is more important than mass per unit area for controlling evaporation (Unger and Parker 1976; Steiner 1989). It has been estimated that the presence of residues on the surface lowers evaporation by 34–50 % (Sauer et al. 1996). Besides residue thickness, the rate of drying is determined by the atmospheric evaporative potential (Tolk et al. 1999). In general, residue characteristics, which affect energy balance components, have a large impact on evaporation fluxes and are strongly influenced by the effect of the year and by the nonuniform distribution (Sauer et al. 1997).

As a direct beneficial effect, soil moisture is conserved under CA systems and more water is available for crops. Azooz and Arshad (1996) found higher soil water contents under zero tillage compared with moldboard plow in British Columbia. In Zimbabwe, mulching helped conserve soil water in a season with long periods without rain at several experimental sites (Mupangwa et al. 2007). Gicheru (1994) showed that crop residue mulching resulted in more moisture down the profile (0–120 cm) during two consecutive crop periods (the short rains and the long rains) than conventional tillage and tied ridges in a semiarid area of Kenya. Thus, tillage and residue management may significantly affect crop yields during years of poor rainfall distribution (Johnson and Hoyt 1999) making permanent soil cover essential for cropping systems aimed at long-term agricultural sustainability.

22.3.4 Soil Nutrients

Maintenance of soil nutrient availability and soil fertility, in general, is the first condition of any permanent system of agriculture. Under conventional agriculture, soil chemical fertility is steadily lost—as crops and crop residues are removed, SOM is plowed and uncovered land oxidizes into carbon dioxide (a GHG) and water.

In CA, cover crops contribute to accumulate organic matter in the surface soil horizon (Alvear et al. 2005; Diekow et al. 2005)—this effect is more significant when cover crops are combined with NT—which is important due to the regulatory role of organic matter in most biological, physical, and chemical processes, which collectively determine soil health. Besides favoring infiltration and water retention, helping to stabilize soil structure to mitigate the impact of wheel traffic and cultivators, and reducing the potential for wind and water erosion, organic matter is an important source of C and a major reservoir for plant nutrients.

Consequently, increased stratification and nutrient availability is generally observed in CA soils (Duiker and Beegle 2006; Franzluebbers and Hons 1996) due to surface placement of crop residues (Unger 1991). Slower decomposition of surface-placed residues (Balota et al. 2004) may prevent rapid leaching of nutrients through the soil profile; however, the possible development of more continuous pores under zero tillage leads to more rapid passage of soluble nutrients deeper into the soil profile (Kay 1990).

N availability is strictly dependent on the rate of C mineralization. CA is normally associated with lower N availability due to greater immobilization of residues (Bradford and Peterson 2000); however, the net immobilization phase is transitory while the higher, but temporary immobilization of N in CA systems over the long term reduces leaching and denitrification losses. Residues from legume cover crops—which are associated with belowground biological agents and provide food for microbial populations—generally provide more carbon and nitrogen under NT compared with plowing (Campbell et al. 1996a, b).

The composition of residues, indeed, will affect their decomposition and consequent nutrient release; the C/N ratio, initial residue N, lignin, polyphenols, and soluble C concentrations are among the most used criteria for residue quality (Moretto et al. 2001). N immobilization can occur as a consequence of cereal residue retention, particularly during the first years of implementation (Erenstein 2002). Several studies have shown that P extractable levels are higher in no-tilled soils principally due to the reduced mixing of P fertilizers with soils, leading to lower P fixation (Duiker and Beegle 2006; Du Preez et al. 2001; Edwards et al. 1992). Higher P tends to accumulate in the topsoil of no-tilled soils in the absence of surface residues. If mulch is present, the soil surface is likely to be moister than conventionally tilled soils.

CA conserves and increases the availability of nutrients such as K near the soil surface where roots are present (Franzluebbers and Hons 1996). However, most research has shown that tillage does not affect Ca and Mg levels especially in clay soils (Govaerts et al. 2007; Duiker and Beegle 2006; Du Preez et al. 2001). Other authors reported increased available Ca and Mg concentrations to 60 cm depth in both oxisol and alfisol under CA (Sidiras and Pavan 1985). Micronutrient cations (Zn, Fe, Cu, and Mn) are usually present in higher levels under CA systems compared to conventional tillage due to surface placement of crop residues (Franzluebbers and Hons 1996). The higher organic matter content at the soil surface, commonly observed under CA, can increase the cation exchange capacity (CEC) of the topsoil (Duiker and Beegle 2006; Govaerts et al. 2007).

In CA, reduced nutrient leaching is not only linked to NT or crop residues but also to the use of catch crops grown during the wetter periods. In general, CA practices tend to favor soil biota, which are important not only because they favor the fast recycling of nutrients (Van Kessel et al. 1994; Drinkwater et al. 1998; Lafond et al. 2008) but also because they help to immobilize most residual nitrogen (along with organic carbon) in the soil (Amado and Costa 2004).

22.4 Climate Change and Gaseous Emission Dynamics

22.4.1 Methane

Methane (CH_4) is the third most important and abundant GHG after H_2O and CO_2 and is 34 times more potent as a heat-trapping gas than CO_2 over a 100-year time scale (IPCC, 2013). Despite a short residence in the atmosphere (ca. 10 years), CH_4 is chemically reactive in the troposphere and stratosphere. Biogenic sources, which account for more than 70 % of the global total, are mainly northern and tropical wetlands, rice paddies, enteric fermentation, forests, oceans, and landfills. Non-biogenic CH_4 includes mainly industry related and geological sources, biomass, and waste treatments (IPCC 2007).

Methanogenesis is a form of anaerobic respiration, where CO_2 or a simple organic carbon compound serves as the final electron acceptor; this activity is performed by *Archaea*, a domain of single-celled microorganisms. Conversely, the primary sinks of CH_4 are the oxidation of the gas to CO_2 in the troposphere (Wuebbles and Hayhoe 2002) and oxidation by methanotrophic bacteria in the aerobic zone of methanogenic soils and in upland soils, called methanotrophy (Hütsch 2001; Xu et al. 2003). Methanotropy activity, more effective in often-submerged or water-saturated soils (Nesbit and Breitenbeck 1992), can contribute up to 15 % of the total CH_4 removal (Born et al. 1994). When the soil is submerged, dissolved oxygen rapidly decreases causing development of facultative anaerobic, then microaerophilic, and finally strict anaerobic microorganisms. As a direct consequence, reducing conditions are established and when Eh is around –200 mV, the reduction of CO_2 into CH_4 occurs. Soils can act as a net source or sink for CH_4 depending on the oxidative state of the matrix, hence land use and management practices directly affect CH_4 release to the atmosphere (Yang and Chang 2001).

Conservation tillage techniques are a key strategy to reduce CH_4 emissions, since they can act as a CH_4 sink (Mojeremane et al. 2011). In fact, the disturbance of soil by tillage causes a significant reduction of CH_4 oxidation capacity through the damage of soil structure that influences negatively gaseous diffusivity and perturbs the physicochemical and biological properties that promote growth of oxidizing agents (Lessard et al. 1994). In long-term NT, the potential oxidation of CH_4 was considerably higher, from 2 to 11 times more than conventional tillage and minimum tillage (MT; Hansen et al. 1993; Hütsch 1998; Ussiri et al. 2009; Le Mer and Roger 2001). Soil porosity is a main factor affecting CH_4 emissions and is directly related to soil tillage practices. Lower values of bulk density, as seen in long-term NT when compared with conventional tillage andMT, improve gas diffusion. Furthermore, oxidative activity is more pronounced in topsoil under NT, while beyond the layer characterized by soil tillage in conventional tillage, methanotrophic activity is higher and equivalent to NT soils. The conversion of cropping systems from conventional tillage to NT improves the potential for soil CH_4 abatement, but it is a slow process, which can take some decades to quantitatively align methanotrophic activities (Regina and Alakukku 2010).

The fertilizer application and the management of crop residuals directly affect soil microbial activity and composition. Ammonium-based fertilizers or urea can reduce the soil potential for CH_4 oxidation activity, while nitrate-based applications have no direct effects. Fertilizers containing ammonium (NH_4^+) lead to increased N_2O emissions due to the change of methanotrophic bacteria activity, which begins to oxidize NH_4^+ with consequent increases in N_2O and CH_4 (Acton and Baggs 2011). The surface spreading of fertilizers, compared with incorporation, increases

CH_4 emissions due to direct inhibition of oxidase activity (Bronson et al. 1997). The effect of soil pH in methanogenesis indicates that emission tends to slightly increase at acid pH (Levy et al. 2012), with the optimum between 5.5 and 7.

The effect of soil incorporation of organic material, such as manure or green manure, in upland soils varies depending on the C/N ratio of the material. The state of degradation of the carbon supplied to the soil is relevant and, if anaerobic conditions occur, the more degraded the carbon, the greater the potential CH_4 production (Mudge and Adger 1995). The production of CH_4 and emission to the atmosphere decreases, when the C content and C/N ratio of incorporated residues decrease. Green legume manure releases an abundance of NH_4^+ that competes with mono-oxygenases enzymes increases the release of CH_4 (Nesbit and Breitenbeck, 1992). Conversely, the incorporation of manure, characterized by a higher C content and a relative low C/N ratio, has the potential to stimulate the work of methanogen communities (Hütsch et al. 1993), without affecting CH_4 oxidizers. A high C/N ratio, as in rice straw, corresponds to organic material abounding in labile C, which is readily usable by microflora.

Management of crop residues in the field, together with the addition of soil conditioners, affects the activity of methanogenic communities, which can be ten times more than without these additions (Schütz et al. 1989; Cicerone et al. 1992; Nouchi et al. 2010). The dose of fertilizer applied, as well as the green material, straws, or residues of crop fermentation, has a proportional effect with increasing doses (Denier van der Gon and Neue 1995). In general, increasing SOM by roots exudates and soil residues, together with improved soil structure and microorganism activity, promotes the activity of methanotrophs (Seghers et al. 2003). Conversely, a large microbial activity, especially if related to an organic matter contribution to the soil, results in oxygen consumption, which creates suitable environmental conditions for methanogenic growth (Baggs et al. 2006). Gas emission from surfaces is therefore balanced by these two processes.

Rice paddies are the most studied methanogenic ecosystems; in this environment, methanogenesis and methanotrophy are noticeable. Methane emissions derived from the passive transfer of gas produced in the soil, through aerenchyma and micropores on the leaf blade, vary depending on the variety of rice and are a function of the morphological differences in aerenchyma and roots (Butterbach-Bahl et al. 1997). Organic fertilizers (rice straw, green manure, or farmyard manure)—preferred due to their richness in C—promote CH_4 production more than synthetic fertilizers. Water management can significantly decrease emissions from 60 to more than 90 % if one or more drainage periods are observed (Cai et al. 1997). Conversely, intermittent drainage may increase nitrification and losses of nitrogen by denitrification with the subsequent emission of N_2O. Varietal selection in the case of rice can be a potential strategy to reduce CH_4 emissions, since the composition of various exudates acts directly on methanotrophic communities (Wassmann et al. 1993). In general, soil tillage in paddy fields or transplantation can potentially release CH_4 trapped in soil, while the use of direct seeding can reduce total emissions (Neue 1997). Farmland releases of CH_4, together with nitrous oxide (N_2O), ammonia (NH_3), and nitrates (NO_3^-), are presented in Fig. 22.1.

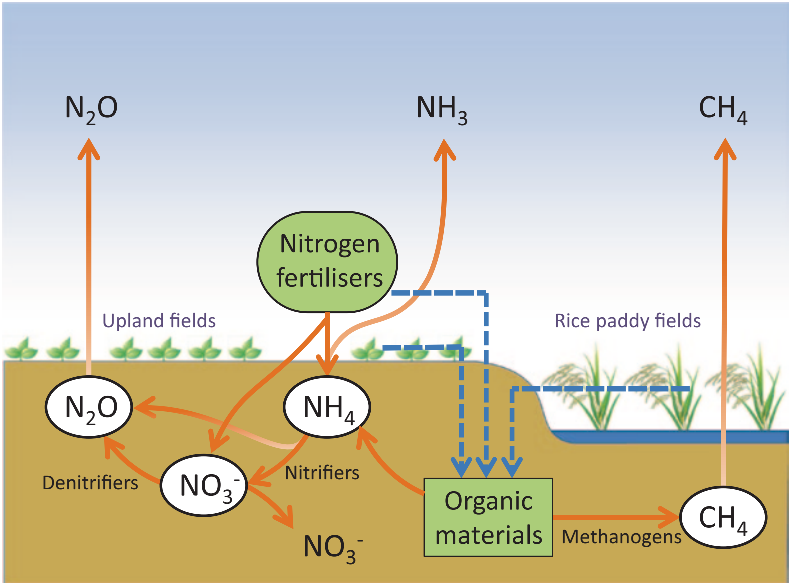

Fig. 22.1 Nitrous oxide (N_2O), methane (CH_4), ammonia (NH_3), and nitrate (NO_3^-) release in farmland. Solid lines are carbon or nitrogen fluxes, dotted lines represent organic materials

22.4.2 Nitrous Oxide

Field crop agriculture is estimated to be the main source of anthropogenic N_2O (IPCC 2001) which contributes more than 61 % of total global N_2O emissions (Montzka et al. 2011). N_2O is 21 times more potent as a heat-trapping gas than CH_4 over a 100-year time scale (IPCC 2007). Once released into the troposphere, N_2O acts as a GHG and takes part in ozone (O_3)-depleting reactions in the stratosphere (Phillips et al. 2007). N_2O is produced from nitrification and denitrification biological processes together with non-biological chemodenitrification. Soil tillage, together with the addition of N compounds as ammonium or nitrate, stimulates microbial activities which produces this reactive gas. Mineral and organic N-fertilizers, together with crop residues and green manures, are recognized as major drivers of N_2O emissions (Bøckman and Olfs 1998). The presence of labile C forms also stimulates denitrification activity due to molecular oxygen consumption in the soil. Moreover, the relationships among soil temperature and pH, soil texture and structure, soil water content, landform and land use, and meteorological conditions are decisive in N_2O emissions.

CA, through zero tillage and MT and practices, directly affects N_2O soil production with highly variable effects (Rochette et al. 2008). In humid climates, in the first 10 years of NT after the conversion from conservation tillage, N_2O emissions were higher and this tendency was counterbalanced by reduced emissions after another 10 years of continuous NT (Six et al. 2004). This variability is related to soil physical, chemical, and biological modifications induced by CA, such as lower soil temperatures reducing N_2O emissions (van Kessel et al. 2013) or progressive increases in water-filled pore spaces (WFPS) that, initially, promote emissions (Smith et al. 2001) and, finally, decrease them once that the soil macroporosity is definitively formed. This effect is also related to soil depth, where nitrification and denitrification activities are greater in the topsoil layer (first 0–10 cm) under NT, whereas at greater depths, denitrification activity is less abundant in conventional tillage (Linn and Doran, 1984). Furthermore, changes in soil pH directly influence the microbial communities that exponentially produce more N_2O from moderate to very strong soil acidity (Blevins et al. 1977; van den Heuvel et al. 2011). In humid climates, increasing soil moisture content detected after conversion from NT or MT practices can be insufficient to significantly increase N_2O emissions by denitrification; in dry climates, increased soil moisture and WFPS with respect to conventional tillage can enhance the denitrification process under humid conditions. Finally, NT practices lead to a general increase in N_2O emissions in poorly aerated soils, while no increase in emissions is observed in well-aerated soils (Rochette 2008).

Crop residue incorporation is a significant source of N_2O with an inverse proportionality between C/N ratio and N_2O emissions. In general, cereal straw incorporation results in higher losses of N_2O with respect to residuals remaining on the soil as mulch (Gregorich et al. 2005). NT practices can increase both nitrification and denitrification processes compared to conventional tillage; straw incorporation in NT significantly increased both processes (Hu et al. 2013). Crop residuals can have a positive effect in reducing soil surface temperature; on the other hand, residuals reduce water evaporation creating in some cases temporarily anaerobic environments that could enhance denitrification and consequently N_2O emissions. Denitrification rates, in fact, are positively correlated with soil moisture (Chen et al. 2011). Although the effects may be controversial, under climate change scenarios where an increase of temperature, CO_2 and a variation in the precipitation distribution are forecast, the role of crop residues as an increasing C source may stimulate denitrification (Butterbach-Bahl and Dannenmann 2011). In some types of grassland, even those with a high potential for C storage, the presence of legumes and their residuals create a higher potential of N_2O emission related to N biological fixation (Rochette and Janzen 2005; Berntsen et al. 2006). The size of crop residues plays an important role, e.g., with pea residues cut into <3 mm lengths, emissions were two times higher than uncut residues, while emissions were not affected by high C/N ratio crop residues such as barley (Ambus et al. 2001). The soil freeze–thaw cycle stimulates C and N mineralization that increases N_2O emissions. The addition of crop residues leads to rapid immobilization of N and a consequent reduction in N_2O emissions if the soil is not C limiting, otherwise addition of C stimulates N_2O production (Pelster et al. 2013). However, cropping systems involving cover crops and characterized by high N-use efficiency had reduced N_2O gaseous emissions (van Groenigen et al. 2011).

N-fertilization placement in CA is relevant; N_2O emissions were significantly reduced, if fertilizers were located below the most biologically active zone (ca. 5 cm depth) with general agronomic advantages (van Kessel et al. 2013). In NT

Table 22.5 Effects on GHG and ammonia (NH_3) emissions on mitigation options at the crop production stage. (modified from Novak and Fiorelli 2010)

Mitigation options for crop production		CH_4	N_2O	CO_2	NH_3
Crop rotation	Increase diversity in crop rotation	–	–	↘	–
	Introduce perennial crops	–	↘	↘	–
	Prolong lifespan of temporary leys	–	↗ after plowing	↘ ↗ after plowing	–
	Cultivate catch crop	–	↘ in short term; ↗? in long term	↘ in short term; ↗? in long term	–
Genetic selection	Breed crops to improve N use efficiency	–	↘?	–	↘?
Fertilization	Synchronize N inputs with crop uptake	–	↘	–	-
	Time effluent application with soil wetness	–	↘	–	↘ or ↗
	Improve fertilization	↘	↘	↘? or ↗?	↘
Soil tillage	Reduce tillage	↘	↘? or ↗?	↘	↗?
	Avoid soil compaction	↘	↘	↘	↘?
	Incorporate crop residues	↗	↗	↘	↘?

↘: mitigation option decreases emissions
↗: mitigation option increases emissions
↘ or ↗: both tendencies have been shown
–: no information given on this compound
?: result needs to be confirmed by more studies

systems, surface spreading of fertilizers leads to greater N_2O emissions than conventional tillage (Ball et al. 1999), while band injection or band placement increases N_2O emissions compared to homogeneous surface spreading, due to the toxic effect of NH_3 release on nitrifying bacteria (Venterea et al. 2010). Finally, NT and MT practices should be practiced for prolonged periods, particularly in dry climates, to efficiently mitigate N_2O emissions. Table 22.5 summarizes the effects of different agricultural management systems in CH_4, N_2O, CO_2 and NH_3 emission potentials.

22.4.3 Ammonia

Ambient NH_3 assumes an important role and growing interest among different atmospheric N reactive species, as a key for future negative impacts of N on terrestrial ecosystems (Sutton 2006). In particular, environmental issues due to NH_3 include soil acidification, water eutrophication with subsequent loss of biodiversity, particulate matter formation, and long-range transport of sulfur (S) and N (Harper 2005). Dry or wet deposition of NH_4^+ particles to the ground contributes to increased environmental loads, such as NO_3^- in groundwater and production of indirect GHG emissions as N_2O and O_3 (Galloway et al. 2008). Most NH_3 emissions in the atmosphere are due to agricultural activities that contribute to more than 50 % of global emissions (Bouwman et al. 1997). NH_3 is mainly produced by conversion of N present in urea and uric acid, excreted by livestock or supplied by mineral fertilizers, to NH_4^+. This transformation occurs rapidly (often within a few days) and requires a key enzyme, urease, which is present in faeces and soil. Furthermore, NH_3 can be produced by conversion of complex organic N forms contained in soil or manures, but this process is slower and could take months.

The main factors influencing the total amount of NH_3 lost from organic and inorganic fertilizers are: typology and concentration of fertilizer, physicochemical characteristics of soil and transfer of NH_3 from surface to atmosphere, and function of the meteorological conditions, i.e., air temperature, wind speed, and solar radiation (Webb et al. 2010). While increased air temperature has a direct impact on the increase in volatilization, rain has an inverse relationship, keeping NH_3 in the aqueous phase in the soil and reducing overall emissions (Sommer and Hutchings 2001).

In dry soils, NH_3 emissions are generally reduced due to ammoniacal solutions, which may be adsorbed and infiltrated through the pores, reducing its contact with air (van der Molen et al. 1989). In contrast, wet or very dry soils reduce infiltration facilitating NH_3 emissions due to the longer fertilizer–air contact. Therefore, increasing the WPFS by reduction tillage or NT can be a helpful agronomical practice to deepen NH_3 solutions into the subsoil. Furthermore, lower temperatures—typical of CA tillage practices—can decrease surface water evaporation, discouraging emissions.

Soil placement and application timing may affect the agronomic efficiency of fertilizer and the relative losses in the atmosphere as NH_3 (Carozzi et al. 2013a). Tillage operations, such as plowing or deep harrowing, after application of organic fertilizers or green manures, contribute to reducing NH_3 emissions by burying the material into the soil. NH_3 abatement efficiency can range up to 90 %, if soil incorporation occurs rapidly compared to surface spreading (Huijsmans et al. 2003, Carozzi et al. 2013b). Consequently, NH_3 emissions are crucial in NT and MT systems, where fertilizers are placed on the soil surface or mixed in the topsoil layer.

NH_3 volatilization from broadcasted urea has a slower dynamic than manure, since the hydrolysis process has to take place under favorable conditions of soil water content and temperature (Terman 1979). NH_3 losses may be greater when urea is applied to residue-covered soil because: (1) urease is active on the crop residual surface, (2) the effect of mulch makes the soil moist and helps the hydrolysis process not in close contact with the soil, and (3) it is more difficult for the urea to reach the soil due to the physical barrier caused by residues. In addition, residues may have a different thermal inertia with respect to the soil by potentially increasing chemical reactions. Moreover, losses tend to be higher from coarse- than fine-textured soils, since fine-textured soils have a higher cation exchange capacity, which can sequestrate more NH_4^+ from soil solution. Therefore, NT may enhance NH_3 volatilization losses from urea-based fertilizers due to the high urease activity associated with residue retention on the soil surface (Sommer et al. 2004). Since nitrate-based fertilizers are less subject to volatilization than ammonium-based ones and soil water retention is enhanced in NT and MT to limit leaching, nitrate-based fertilizers are preferred in CA practices. Moreover, under climate change conditions, it is even more important to avoid keeping ammonium-based fertilizers (both organic or urea forms) on soil surface, especially in CA systems. In this regards, it is useful to consider N-sulfate or nitrate forms, and to develop technologies for direct injection of ammonium-based fertilizer into the soil, or to avoid the contact between ammonium-based fertilizer and crop residues. Variations in meteorology and overall climate can significantly affect NH_3 emissions. The main motivation is that the volatilization phenomenon is directly correlated with increasing temperatures (Skjøth and Geels 2013). This effect is reflected in atmospheric aerosol concentrations, radiative forcing (Xu and Penner 2012), and atmospheric chemistry (Seinfeld and Pandis 2006).

22.5 CA and Water Quality

22.5.1 Runoff and Erosion, Nutrient Losses in Surface Water

Soil erosion represents a threat for agricultural sustainability worldwide (Laflen and Roose 1998). In Europe, soil erosion is one of the most important environmental problems particularly in agricultural systems of the Mediterranean basin (Fig. 22.2). In East and Southeast Asia, available water resources are limiting factors; while there is water available for irrigation, agricultural land resources are becoming scarce (Pisante et al. 2010).

Despite the economic impact on a world-scale, soil erosion is difficult to estimate; it is a function of erosivity and erodibility. Erosivity is related to the physical characteristics of rainfall at the soil surface and runoff velocity: It is therefore affected by crop residues. Erodibility is related to the physical features of soil (Blevins et al. 1998). It is now well acknowledged that long-term use of conventional tillage in certain situations leads to soil compaction and therefore lower yields, increased runoff, and poor infiltration (Hussain et al. 1999a; Ferreras et al. 2000; Raper et al. 2000), ultimately determining the risk of soil erosion. In erosion-prone environments (wet or dried warm zones), inversion of soil by tillage promotes unnecessary moisture loss; at the same time, crop residues that should protect soil from erosion by wind or water and slow soil moisture loss after rain are buried (Pisante 2002).

The higher aggregate stability in CA practices, when compared to conventionally tilled fields or NT fields without residue retention, results in lower soil erosion potential (Govaerts et al. 2007; Li et al. 2007; Pinheiro et al. 2004; Chan et al. 2002; Filho et al. 2002; Hernanz et al. 2002). The positive effect of CA on reduced erodibility is further enhanced by the reduced runoff (Rao et al. 1998, Rhoton et al. 2002). Soil sediments, as a consequence of soil erosion, represent the main contaminants of water flows (Tebrügge and Düring 1999); it is estimated that 27–86 % of eroding sediment leaves the field (Quine and Walling 1993). Associated with this movement of soil and water are nutrients, agrochemicals, pathogens, organic

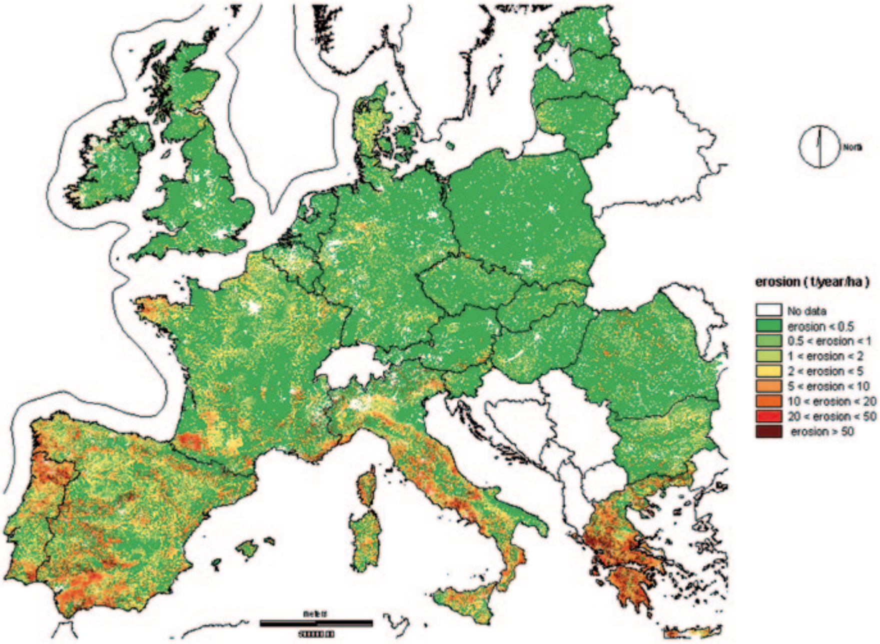

Fig. 22.2 Soil erosion map in Europe. (Kirkby et al. 2004)

matter, and heavy metals (Christensen et al. 1995), all of which frequently damage the water ecosystem (Uri et. al. 1998). Sediments cause sublethal and lethal responses in fresh water fish, aquatic invertebrates, and periphyton (Newcombe and MacDonald 1991). A direct consequence of inorganic fertilizers, organic matter, and pesticides leaching into the water is eutrophication, a widespread phenomenon throughout the world (Harper 1992).

CA is a possible way to reduce the risk of these pollutants reaching surface and ground water. In a 15-year study, comparing different CA techniques, sediment loss was 532, 82, and 1152 kg ha^{-1} per year for chisel-plow and disk versus no-till, respectively (Owens et al. 2002). Soil management affects the rate and proportion of water infiltration and therefore river flow rates and the need for irrigation (Evans 1996). In areas of low rainfall, CA helps retain water in the upper soil layers (Rasmussen 1999). Direct drilling combined with stubble retention increased rain infiltration, leading to reduced runoff compared to cultivated soil (Carter and Steed 1992).

22.5.2 Nitrate Leaching

Nitrate leaching from agricultural systems is one of the most important negative externalities of agricultural systems. Nitrate leaching depends on several interacting factors such as organic and mineral fertilization, cropping system, crop nitrogen uptake, amount of rain, temperature, and soil characteristics (Acutis et al. 2000; Beaudoin et al. 2005; Perego et al. 2012; Zavattaro et al. 2012). All these factors are subject to the effects of climate change and conservation tillage systems; no-till has the possibility to reduce nitrate losses through leaching under climate change conditions (Soane et al. 2012). Tebrügge (2001) supposed lower nitrate leaching in no-tilled soils and Van Den Bossche et al. (2009) showed higher N efficiency in reduced and no-till systems compared to conventional systems as a result of slower organic matter decomposition and therefore slower mineralization and less leaching. Greater nitrogen use efficiency (NUE) in conservation systems has been observed in the USA; this increase in NUE allows for a reduction in leaching when comparison with conventional agriculture, without increasing N_2O emissions (Robertson et al. 2012). These results were partially confirmed by Hansen et al. (2010) who identified situations where leaching was lower in no-tilled soils, while others had lower leaching under conventional tillage. Klein et al. (2013) used the CropSyst model to highlight increases in N-leaching by 30–45 % for two climate scenarios for 2050 in a catchment on the Swiss Central Plateau, and to identify RT as an important option for reducing leaching and erosion.

Another possible impact of climate change is increased cracking in dry periods and increased infiltration during more frequent, intense rainfall events (Stuart et al. 2011), and surface sealing due to the impact of raindrops on the soil surface, causing soil aggregate breakdown and production of fine particles, which reduce macroporosity. In both situations, conservation tillage offers more surface residues to protect soil from raindrops, conserves soil moisture by reducing the shrinking and swelling phenomena in clay soil, reduces the risk of high concentrations of P and N in runoff water, and often reduces leaching by reducing the macroporosity.

22.6 Research and Knowledge Transfer

Scientific research is the main driver of innovation, creating new knowledge and technology that can be transferred and adapted to different situations. This view is usually described as the “linear” or “transfer of technology” model. The second view, while not denying the importance of research and technology transfer, recognizes innovation as an interactive process. Innovation involves the interaction of individuals and organizations possessing different types of knowledge to include not only knowledge creation but also the whole system of technological diffusion, adoption processes and interaction adjustments. Future solutions will require interactive relationships among basic science, applied science, and technology development (OECD 2009). The important role of agronomy research and effort technology transfer system for enhancing the effect of CA in relation to climate change, as in other areas, is strongly linked to the quantity and quality of available data. In the contemporary agricultural sector, competitiveness depends on collaboration for innovation. Increasingly, “innovation systems” are viewed as a network of knowledge flows with considerable two-way flows of information upstream and downstream and knowledge spillover among participants that are connected in formal and informal ways. This more systemic approach suggests that innovation policy goes far beyond research expenditure and involves a wide range of institutions that can affect incentives, knowledge sharing, and the processes used for commercialization. The estimated benefits of agricultural research generally far exceed its costs, with the literature reporting annual internal rates of return that range between 20 and 80 % (Alston 2010).

A conceptual framework containing elements of an agricultural innovation system for adaptation to climate change could be developed, as well as multiple indicators that would help assess the performance of each aspect of an innovation system in agriculture across countries. Knowledge, information, and technology are increasingly generated, diffused, and applied through the private sector. Exponential growth in information and communications technology (ICT), especially the Internet, has transformed the ability to take advantage of knowledge developed in other places or for other purposes. The knowledge structure of the agricultural sector in many countries is changing markedly (OECD 2011). Evidence of linkages between research, productivity growth, and competitiveness also stress the need to adopt an approach with more innovation systems, like in agriculture.

The mitigation of adverse effects of climate change and exploration of new solutions for agriculture in an increasingly globalized comparison could help to identify the most appropriate policy directions in support of research and development (Nisbet 2009). Future work should take a closer look at institutional arrangements in agricultural innovation and knowledge systems, and examine the respective roles of governments and the private sector in strengthening innovation systems and facilitating technological adoption. In this respect, some measures to take are (1) presence of research collaboration across sectors, (2) protection of intellectual property rights, and (3) knowledge flow. A comprehensive effort should be undertaken to measure the different stages of an innovation system, for example, by testing its technological adoption and diffusion at the farm level, and to investigate the impact of agricultural policies on technological change and technical efficiency. The nature of production systems, within contemporary climate change, has been the transformation from high-disturbance production systems with a high environmental impact to low-disturbance agroecological systems, where production technologies and practices (i.e., CA) are more in harmony with the ecosystem process and where both productivity and environmental services can be harnessed. Multi-stakeholder innovation systems have an important role to play in generating relevant technologies that can be adopted and adapted by farmers, who must be an integral part of any effective innovation system. Training actions creating the possibility for "fast track" applications and evaluations under different specific conditions could be considered, though are more common for students and less common for farmers and more popular among research institutions and extension offices, where they exist. The spread of CA worldwide has been achieved where: (1) farmers have been informed of the system and convinced of its benefits by experience; (2) training and technical support to early adopters have been provided; and (3) adequate support policies exist (e.g., funding through carbon sequestration contracts with farmers).

22.7 Conclusions

This chapter reviews the main interactions of CA systems with climate change, especially on sectors like agriculture, where the lifecycle of crops is mainly determined by climate conditions. At national and state levels, the adoption of CA policies is often congruent and supportive of other policies related to the environment, natural resources, energy efficiencies, and more recently, climate change.

The adoption of CA can significantly affect the emission of GHG and NH_3, especially if good agricultural practices, mainly related to the efficient use of fertilizers, are observed. Reduced or NT leads to direct drops in N_2O emissions, CH_4 and CO_2 sinks, while the incorporation of crop residues causes a general increase in N_2O and CH_4, and a potential reduction in NH_3 and NO_3^-. Improved NUE can greatly reduce the emission of N reactive forms, as N_2O, NH_3, and NO_3^-, towards the atmosphere and groundwater. In relation to increasing temperatures, the emissions of N_2O and NH_3 are directly correlated, while CH_4 is negatively correlated, to air and soil temperatures. The changes in precipitation frequency and intensity in some areas may noticeably affect the release of these pollutants, because they are directly correlated to NO_3^- leaching and the emission of N_2O and CH_4, mainly due to conditions of soil aeration. In this regard, CA techniques which greatly improve soil porosity and reduce soil temperature are advantageous practices to mitigate these releases into the environment.

For productive and remunerative agriculture, which at the same time preserves and enhances the natural resource base and environment, and positively contributes to harnessing environmental services, CA represents a task for Sustainable Crop Production Intensification (SCPI) to not only reduce the impact of climate change on crop production but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Hence, it adapts to and mitigates climate change and leads to a more efficient use of inputs to reduce production costs. Intensification should also enhance biodiversity—above- and belowground level—in crop production systems to improve ecosystem services for better productivity and a healthier environment (Pisante et al. 2012). Investments in knowledge—especially in the form of science and technology—have featured prominently and consistently in most strategies to promote sustainable and equitable agricultural development at the national level.

In crux, CA as a basis for SCPI is essential and practicable, but depends on both how and what crops are grown, as well as on the engagement of all stakeholders who are aligned towards transforming the unsustainable tillage-based farming systems to CA systems regardless of soil, climate, and ecosystem services. This transformational change is now occurring worldwide on all continents and ecologies and covers nearly 10 % of global arable land. In any case, there is the need to standardize research activities because often contradictory results are due to incomplete implementation of the basic principles of CA (Derpsch et al. 2014). In the authors' opinion, well-managed experiments indicate greater resistance and resilience of CA systems to climate changes, and that the most critical point could be the control of gaseous emissions of N_2O, and that this is a specific requirement.

An example of ecosystem services operating in different parts of the world and including a carbon offset scheme for agricultural land use is in Alberta, Canada. The province of Alberta, which has a strong agriculture-based economy and also the highest GHG emissions in the country (due to oil and gas production), first adopted a climate change action plan in 2002. Since 2007 this has included the implementation of a CA system protocol on agricultural lands as an opportunity for direct and indirect reductions of GHG emissions through carbon offset trading with industry (Goddard et al. 2009). These important lessons learnt from around the world regarding the high potential for carbon sequestration with CA systems and the associated opportunity for carbon trading and reduction in GHGs emissions should be taken into consideration in any climate change mitigation and sustainable crop production strategy for the future.

References

Acton SD, Baggs EM (2011) Interactions between N application rate, CH_4 oxidation and N_2O production in soil. Biogeochemistry 103:15–26

Acutis M, Ducco G, Grignani C (2000) Stochastic use of the LEACHN model to forecast nitrate leaching in different maize cropping systems. Eur J Agron 13:191–206

Ainsworth EA, Long SP (2005) What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytol 165:351–372

Akbolat D, Evrendilek F, Coskan A, Ekinci K (2009) Quantifying soil respiration in response to short-term tillage practices: a case study in southern Turkey. Acta Agric Scand Sect B Plant Soil Sci 59:50–56

Alexander LV, Zhang X, Peterson TC, Caesar J, Gleason B, Klein Tank AMG (2006) Global observed changes in daily climate extremes of temperature and precipitation (1984–2012). J Geophys Res Atmos 111(D5)

Al-Kaisi M (2008) Impact of tillage and crop rotation systems on soil carbon sequestration. Iowa State University, Iowa

Alston J (2010) The benefits from agricultural research and development, innovation, and productivity growth. OECD Food, agriculture and fisheries working papers, No. 31. OECD Publ., Paris, France

Alvear M, Rosas A, Rouanet JL, Borie F (2005) Effects of three soil tillage systems on some biological activities in an Ultisol from southern Chile. Soil Till Res 82:195–202

Alves AC, Setter TL (2004) Response of cassava leaf area expansion to water deficit: cell proliferation, cell expansion and delayed development. Ann Bot 94:605–613

Alves BJR, Zotarelli L, Boddey RM, Urquiaga S (2002) Soybean benefit to a subsequent wheat cropping system under zero tiIlage In: Nuclear techniques in integrated plant nutrient, water and soil management: proceedings of a Symposium held in Vienna, 16–20 October 2000 Vienna: IAEA 2002, pp 87–93

Alves BJR, Boddey RM, Urquiaga S (2003) The success of BNF in soybean in Brazil. Plant Soil 252:1–9

Alves BJR, Zotarelli L, Fernandes FM, Heckler JC, Macedo RAT, Boddey RM, Jantalia CP, Urquiaga S (2006) Biological nitrogen fixation and nitrogen fertilizer on the nitrogen balance of soybean, maize and cotton. Pesq Agrop Bras 41-3:449–456

Amado TJC, Costa CN (2004) Solos sob sistema Plantio Direto no Brasil podem atuar como importante tampão ambiental. Jornal Direto no Cerrado 37:21–22

Amado TJC, Mielniczuck J, Fernandes SBV, Bayer C (1999) Culturas de cobertura, acúmulo de nitrogenio total no solo e produtividade de milho. Rev Bras Ciência Solo 23:679–686

Amado TJC, Bayer C, Eltz FLF, Brum AC (2001) Potencial de culturas de cobertura em acumular carbono e nitrogenio no solo no plantio direto e a melhoria da qualidade ambiental. Rev Bras Ciência Solo 25:189–197

Ambus P, Jensen ES, Robertson GP (2001) Nitrous oxide and N-leaching losses from agricultural soil: influence of crop residue particle size, quality and placement, Phyton-Ann. REI Bot 41:7–15

Andersen A (1999) Plant protection in spring cereal production with reduced tillage. II. Pests and beneficial insects. Crop Prot 18:651–657

Angers DA, Bolinder MA, Carter MR, Gregorich EG, Drury CF, Liang BC, Voroney RP, Simard RR, Donald RG, Beyaert RP, Martel J (1997) Impact of tillage practices on organic carbon and nitrogen storage in cool, humid soils of eastern Canada. Soil Till Res 41:191–201

Azooz RH, Arshad MA (1996) Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. Can J Soil Sci 76:143–152

Baggs EM, Chebii J, Ndufa JK (2006) A short-term investigation of trace gas emissions following tillage and no-tillage of agroforestry residues in western Kenya. Soil Till Res 90:69–76

Bailey VL, Smith JL, Bolton HJ (2002) Fungal-to-bacterial ratios in soils investigated for enhanced carbon sequestration. Soil Biol Biochem 34:1385–1389

Baker JM, Ochsner TE, Venterea RT, Griffis TJ (2007) Tillage and soil carbon sequestration-what do we really know? Agric Ecosyst Environ 118:1–5

Balabane M, Bureau F, Decaens T, Akpa M, Hedde M, Laval K, Puget P, Pawlak B, Barray S, Cluzeau D, Labreuche J, Bodet JM, Le Bissonnais Y, Saulas P, Bertrand M, Guichard L, Picard D, Houot S, Arrouays D, Brygoo Y, Chenu C (2005) Restauration de fonctions et proprietes des sols de grande culture intensive: effets de systemes de culture alternatifs sur les matieres organiques et la structure des sols limoneux, et approche du role fonctionnel de la diversitè biologique des sols. GESSOL/projet Dmostra. Rapport final, p 119

Ball BC, Scott A, Parker JP (1999) Field N_2O, CO_2 and CH_4 fluxes in relation to tillage, compaction and soil quality in Scotland. Soil Till Res 53:29–39

Balota EL, Colozzi A, Andrade DS, Dick RP (2004) Long-term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. Soil Till Res 77:137–145

Barnes BT, Ellis FB (1979) Effects of different methods of cultivation and direct drilling and disposal of straw residues on populations of earthworms. J Soil Sci 30:679

Battisti DS, Naylor RL (2009) Historical warnings of future food insecurity with unprecedented seasonal heat. Science 323:240–244

Bayer C, Bertol I (1999) Características químicas de um Cambissolo húmico afetadas por sistemas de preparo, com enfase à matéria organica. Rev Bras Ciência Solo 23:687–694

Bayer C, Mielniczuck J (1997) Nitrogênio total de um solo submetido a diferentes métodos de preparo e sistemas de culturas. Rev Bras Ciência Solo 21:235–239

Bayer C, Martin-Neto L, Mielniczuck J, Ceretta CA (2000a) Effect of no-tillage cropping systems on SOM in a sandy clay loam Acrisol from Southern Brazil monitored by electron spin resonance and nuclear magnetic resonance. Soil Till Res 53:95–104

Bayer C, Mielniczuck J, Amado TJC, Martin-Neto L, Fernandes SBV (2000b) Organic matter storage in a sandy clay loam Acrisol affected by tillage and cropping systems in southern Brazil. Soil Till Res 54:101–109

Beare MH, Parmelee RW, Hendrix PF, Cheng W, Coleman DC, Crossley DA (1992) Microbial and faunal interactions and effects on litter nitrogen and decomposition in agroecosystems. Ecol Monogr 62:569–591

Beare MH, Pohlad BR, Wright DH, Coleman DC (1993) Residue placement and fungicide effects on fungal communities in conventional and no-tillage soils. Soil Sci Soc Am J 57:392–399

Beaudoin N, Saad JK, Van Laethem C, Machet JM, Maucorps J, Mary B (2005) Nitrate leaching in intensive agriculture in Northern France: effect of farming practices, soils and crop rotations. Agric Ecosyst Environ 111:292–310

Ben Moussa-MachraouiS, Errouissi F, Ben-Hammouda M, Nouira S (2010) Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semi-arid conditions in North-Western Tunisia. Soil Till Res 106:247–253

Berntsen J, Grant R, Olesen JE, Kristensen IS, Vinther FP, Molgaard JP, Petersen BM (2006) Nitrogen cycling in organic farming systems with rotational grass-clover and arable crops. Soil Use Manage 22:197–208

Bindi M, Olesen JE (2011) The responses of agriculture in Europe to climate change. Reg Environ Change 11:S151–158

Bindi M, Fibbi L, Gozzini B, Orlandini S, Miglietta F (1996) Modeling the impact of future climate scenarios on yield and yield variability of grapevine. Clim Res 7:213–224

Black HIJ, Okwakol MJN (1997) Agricultural intensification, soil biodiversity and agroecosystem function in the tropics: the role of termites. Appl Soil Ecol 6:37–53

Black AL, Tanaka DL (1997) A conservation tillage-cropping systems study in the Northern Great Plains of the United States. In: Paul EA et al (eds) Soil organic matter in temperate agroecosystems—Long-term experiments in North America. CRC, New York, 335–342

Blanchart E, Albrecht A, Brown G, Decaens T, Duboisset A, Lavelle P, Mariani L, Roose E (2004) Effects of tropical endogeic earthworms on soil erosion. Agric Ecosyst Environ 104:303–315

Blevins RL, Thomas GW, Cornelius PL (1977) Influence of no-tillage and nitrogen fertilization on certain soil properties after 5 years of continuous corn. Agron J 69:383–386

Blevins RL, Lal R, Doran JW, Langdale GW, Frye WW (1998) Conservation tillage for erosion-control and soil quality. In: Pierce FJ, Frye WW (eds) Advances in soil and water conservation. Ann Arbor Press, Michigan, pp 51–68

Bøckman OChr OHW (1998) Fertilizers, agronomy and N_2O. Nutr Cycl Agroecosyst 52:165–170

Boddey RM, de Moraes SJC, de Alves M, Urquiaga BJR (1997) The contribution of biological nitrogen fixation for sustainable agricultural systems in the tropics. Soil Biol Biochem 29:787–799

Boddey RM, Alves BJR, Soares LH deB, Jantalia CP, Urquiaga S (2009) Biological nitrogen fixation and mitigation of greenhouse gas emissions. In: Emerich DW, Krishnan HB (eds) Agronomy Monograph Nitrogen Fixation in Crop Production. Am Soc Agron, Crop Sci Soc Am, and Soil Sci Soc Am Madison, Wisconsin, pp 387–413

Bol R, Kandeler E, Amelung W, Glaser B, Marx MC, Preedy N, Lorenz K (2003) Short-term effects of dairy slurry amendment on carbon sequestration and enzyme activities in a temperate grassland. Soil Biol Biochem 35:1411–1421

Boone FR, Slager S, Miedema R, Eleveld R (1976) Some influences of zero-tillage on the structure and stability of fine textured river levee soil. Neth J Agric Sci 24:105–119

Born M, Dorr H, Levin J (1994) Methane consumption in aerated soils of the temperate zone. Tellus B 42:2–8

Bouwman AF, Lee DS, Asman AH, Dentener EJ, Van Der Hoe KW, Olivier JGJ (1997) A global high-resolution emission inventory for ammonia. Global Biogeochem Cycles 11:561–587

Bradford JM, Peterson GA (2000) Conservation tillage. In: Summer ME (ed) Handbook of soil science. CRC, Boca Raton, pp G247–269

Bronson KF, Neue HU, Singh U, Abao EB Jr (1997) Automated chamber measurements of methane and nitrous oxide flux in a flooded rice soil: I. Residue nitrogen and water management. Soil Sci Soc Am J 61:981–987

Butterbach-Bahl K, Dannenmann M (2011) Denitrification and associated soil N_2O emissions due to agricultural activities in a changing climate. Curr Opin Environ Sustain 3:389–395

Butterbach-Bahl K, Papen H, Rennenberg H (1997) Impact of gas transport through rice cultivars on methane emission from rice paddy fields. Plant Cell Environ 20:1175–1183

Buyanovsky GA, Wagner GH (1998) Carbon cycling in cultivated land and its global significance. Global Change Biol 4:131–141

Carter MR, Steed GR (1992) The effects of direct-drilling and stubble retention on hydraulic-properties at the surface of duplex soils in North-Eastern Victoria. Aust J Soil Res 30:505–516

Cai ZC, Xing GX, Yan XY, Xu H, Tsuruta H, Yagi K, Minami K (1997) Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilizers and water management. Plant Soil 196:7–14

Campbell CA, McConkey BG, Zentner RP, Dyck FB, Selles F, Curtin D (1996a) Longterm effects of tillage and crop rotations on soil organic C and total N in a clay soil in southwestern Saskatchewan. Can J Soil Sci 76:395–401

Campbell CA, McConkey BG, Zentner RP, Selles F, Curtin D (1996b) Tillage and crop rotation effects on soil organic C and N in a coarse-textured Typic Haploboroll in southwestern Saskatchewan. Soil Till Res 37:3–14

Campbell CA, Lafond GP, Moulin AP, Townley-Smith L, Zentner RP (1997) Crop production and soil organic matter in long-term crop rotations in the sub-humid northern Great Plains of Canada. In: Paul EA et al. (eds) Soil organic matter in temperate agroecosystems-Long-term experiments in North America. CRC, New York, 297–315

Cantero-Martinez C, Gabina D, Arrue JL (2007) Evaluation of conservation agriculture technology in Mediterranean agriculture systems. In: Fares SB, Asfary A, Belloum A, Steiner K, Friedrich T (eds) Proceedings of the International Workshop on Conservation Agriculture for Sustainable Land Management to Improve the Livelihood of People in Dry Areas 2007 May 7–9, Damascus, Syria. ACSAD and GTZ, p 157–164

Carozzi M, Loubet B, Acutis M, Rana G, Ferrara RM (2013a) Inverse dispersion modelling highlights the efficiency of slurry injection to reduce ammonia losses by agriculture in the Po Valley (Italy). Agric Forest Meteorol 171-172:306–318

Carozzi M, Ferrara RM, Rana G, Acutis M (2013b) Evaluation of mitigation strategies to reduce ammonia losses from slurry fertilisation on arable lands. Sci Total Environ 449:126–133

Chadwick DR, van der Weerden T, Martinez J, Pain BF (1998) Nitrogen transformations and losses following pig slurry applications to a natural soil filter system (Solepur process) in Britany, France. J Agr Eng Res 69:85–93

Chan KY (1997) Consequences of changes in particulate organic carbon in vertisols under pasture and cropping. Soil Sci Soc Am J 61:1376–1382

Chan KY (2001) An overview of some tillage impacts on earthworm population abundance and diversity—implications for functioning in soils. Soil Till Res 57:179–191

Chan KY, Heenan DP (1993) Surface hydraulic-properties of a red earth under continuous cropping with different management-practices. Aust J Soil Res 31:13–24

Chan KY, Bowman A, Oates A (2001) Oxidizible organic carbon fractions and soil quality changes in an oxic paleustalf under different pasture leys. Soil Sci 166:61–67

Chan KY, Heenan DP, Oates A (2002) Soil carbon fractions and relationship to soil quality under different tillage and stubble management. Soil Till Res 63:133–139

Chantigny MH, Rochette P, Angers DA (2001) Short-term C and N dynamics in a soil amended with pig slurry and barley straw: a field experiment. Can J Soil Sci 81:131–137

Chen YT, Borken W, Stange CF, Matzner E (2011) Effects of decreasing water potential on gross ammonification and nitrification in an acid coniferous forest soil. Soil Biol Biochem 43:333–338

Christensen B, Montgomery JM, Fawcett RS, Tierney D (1995) Best management practices for water quality. Conservation Technology Information Center, West Lafayette, pp 1–3

Cicerone RJ, Delwiche CC, Tyler SC, Zimmerman PR (1992) Methane emissions from California rice paddies with varied treatments. Global Biogeochem Cycles 6:233–248

Clausen JC, Jokela WE, Potter FI, Williams JW (1996) Paired watershed comparison of tillage effects on runoff, sediment, and pesticide losses. J Environ Qual 25:1000–1007

Cleland EE, Chuine I, Menzel A, Mooney HA, Schwartz MD (2007) Shifting plant phenology in response to global change. Trends Ecol Evol 22:357–365

Cochran VL, Sparrow SD, Sparrow EB (1994) Residue effect on soil micro- and macroorganisms. In: Unger PW (ed) Managing agricultural residues. CRC, Boca Raton, pp 163–184

Confalonieri R, Donatelli Bregaglio S, Tubiello FN, Fernandes E (2012) Agroecological zones simulator: A component based, open-access, transparent platform for climate change - crop productivity impact assessment in Latin America. iEMSs 6th International Congress, Leipzig, 1–5 July

Corsi S, Friedrich T, Kassam A, Pisante M, Sà J de M (2012) Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: a literature review. Integrated crop management, vol 16. Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome

Dai A, Fung IY, DelGenio AD (1997) Surface observed global land precipitation variations during 1900-1998. J Climate 10:2943–2962

Dass A, Sudhishri S, Lenka NK, Patnaik US (2010) Runoff capture through vegetative barriers and planting methodologies to reduce erosion, and improve soil moisture, fertility and crop productivity in southern Orissa. India Nutr Cycl Agroecosyst 10:1–13

De Alba S, Lacasta C, Benito G, Perez-Gonzalez A (2001) Influence of soil management on water erosion in a Mediterranean semi-arid environment in Central Spain. In: Garcıa-Torres L, Benites J, Martınez-Vilela A (eds) Conservation agriculture, a worldwide challenge, vol 2. ECAF and FAO, Spain

De laRD, Diaz-Pereira E, Mayol F, Czyz EA, Dexter AR, Dumitru E, Enache R, Fleige H, Horn R, Rajkay K, Simota C (2005) SIDASS project Part2. Soil erosion as a function of soil type and agricultural management in Sevilla olive area, Southern Spain. Soil Till Res 82:19–28

de Maria IC, Nnabude PC, de Castro OM (1999) Long-term tillage effects on soil chemical properties of a Rhodic Ferralsol in Southern Brazil. Soil Till Res 51:71–79

De MSàJCM, Cerri CC, Dick WA, Lal R, Filho SPV, Piccolo MC, Feigl BE (2001) Organic matter dynamics and carbon sequestration rates for a tillage chronosequence in a Brazilian Oxisol. Soil Sci Soc Am J 65:1486–1499

Decaëns T, Jimenez JJ (2002) Earthworm communities under an agricultural intensification gradient in Colombia. Plant Soil 240:133–143

Deibert EJ, Utte RA, Schwert DP (1991) Tillage system influence on earthworms (Lumbricidae) in North Dakota. N Dak Farm Res 48:10–12

Del Río S, Herrero L, Pinto-Gomes C, Penas A (2011) Spatial analysis of mean temperature trends in Spain over the period 1961–2006. Glob Planet Change 79:65–75

Denier vanderGHAC, Neue HU (1995) Influence of organic matter incorporation on the methane emission from a wetland rice field. Glob Biogeochem Cycles 9:11–22

Dennis P, Thomas MB, Sotherton NW (1994) Structural features of field boundaries which influence the overwintering densities of beneficial arthropod predators. J Appl Ecol 31:361–370

Derpsch R, Franzluebbers AJ, Duiker SW, Reicosky DC, Koeller K, Friedrich T, Sturny WG, Sa´ JCM, Weiss K (2014) Why do we need to standardize no-tillage research? (Letter to the Editor). Soil Till Res 137:16–22

Diekow J, Mielniczuk J, Knicker H, Bayer C, Dick DP, Kogel-Knabner I (2005) Soil C and N stocks as affected by cropping systems and nitrogen fertilisation in a Southern Brazil Acrisol managed under no-tillage for 17 years. Soil Till Res 81:87–95

Doran JW, Parkin TB (1994) Defining and assessing soil quality. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA (eds) Defining soil quality for a sustainable environment. SSSA special publication no. 35, Madison, pp 3–21

Doran JW, Liebig MA, Santana DP (1998) Soil health and global sustainability. In: Transactions of the 16th World Congress of Soil Science. Montepellier. 20–26 August, France

Drijber RA, Doran JW, Parkhurst AM, Lyon DJ (2000) Changes in soil microbial community structure with tillage under long-term wheat-fallow management. Soil Biol Biochem 32:1419–1430

Drinkwater LE, Wagoner P, Sarrantonio M (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. Nature 396:262–265

Du Preez CC, Steyn JT, Kotze E (2001) Long-term effects of wheat residue management on some fertility indicators of a semi-arid Plinthosol. Soil Till Res 63:25–33

Duiker SW, Beegle DB (2006) Soil fertility distributions in long-term no-till, chisel/disk and moldboard plow/disk systems. Soil Till Res 88:30–41

Eagle AJ, Henry LR, Olander LP, Haugen-Kozyra KH, Millar N, Robertson GP (2011) Greenhouse gas mitigation potential of agricultural land management in the United States: a synthesis of the literature, 2nd edn. Nicholas Institute for Environmental Policy Solutions, Durham, North Carolina

Easterling W, Apps M (2005) Assessing the consequences of climate change for food and forest resources: a view from the IPCC. Clim Change 70:165–189

Edwards CA, Bohlen PJ (1996) Biology and ecology of earthworms. Chapman and Hall, London

Edwards JH, Wood CW, Thurlow DL, Ruf ME (1992) Tillage and crop-rotation effects on fertility status of a hapludult soil. Soil Sci Soc Am J 56:1577–1582

Entry IA, Mitchell CC, Backman CB (1996) Influence of management practices on soil organic matter, microbial biomass and cotton yield in Alabama's "Old Rotation". Biol Fertil Soils 23-4:353–358

Erenstein O (2002) Crop residue mulching in tropical and semi-tropical countries: an evaluation of residue availability and other technological implications. Soil Till Res 67:115–133

Evans R (1996) Soil erosion and its impacts in England and Wales. Friends of the Earth, London, p 121

FAO (2001) World Soil Resources Reports 96: Soil carbon sequestration for improved land management. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2008) The case for improving soil health. In: Proceedings of the International Technical Workshop on Investing in Sustainable Crop Intensification, 22–24 July. Integrated Crop Management, vol 6. FAO, Rome

FAO (2009) Food security and agricultural mitigation in developing countries: options for capturing synergies. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2011) What is conservation agriculture? FAO conservation agriculture website. http://www.fao.org/ag/ca/1a.html

FAO (2012) Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: a literature review. Integr Crop Manag 16:89

FAO (2014) FAOSTAT database. FAO, Rome, Italy. http://www.fao.org/faostat. Accessed 10 Feb 2014

Farrar JF (1996) Sinks, integral parts of a whole plant. J Exp Bot 47:1273–1279

Ferguson HJ, McPherson RM (1985) Abundance and diversity of adult carabidae in 4 soybean cropping systems in Virginia. J Entomol Sci 20:163–171

Ferreras LA, Costa JL, García FO, Pecorari C (2000) Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern "Pampa" of Argentina. Soil Till Res 54:31–39

Filho CC, Lourenco A, Guimaraes MDF, Fonseca ICB (2002) Aggregate stability under different soil management systems in a red latosol in the state of Parana, Brazil. Soil Till Res 65:45–51

Flessa H, Beese F (2000) Laboratory estimates of trace gas emissions following surface application and injection of cattle slurry. J Environ Qual 29:262–268

Folgarait PJ (1998) Ant biodiversity and its relationship to ecosystem functioning: a review. Biodivers Conserv 7:1221–1244

Fontaine S (2007) Stability of organic carbon in deep soil layers controlled by fresh carbon supply. Nature 450:277–280

Fontaine S, Bardoux G, Abbadie L, Mariotti A (2004) Carbon input to soil may decrease soil carbon content. Ecol Lett 7:314–320

Francis GS, Knight TL (1993) Long-term effects of conventional and no-tillage on selected soil properties and crop yields in Canterbury, New Zealand. Soil Till Res 26:193–210

Franzaring J, Högy P, Fangmeier A (2008) Effects of free-air CO_2 enrichment on the growth of summer oilseed rape (Brassica napus cv. Campino). Agric Ecosyst Environ 128:127–134

Franzluebbers AJ, Hons FM (1996) Soil-profile distribution of primary and secondary plantavailable nutrients under conventional and no tillage. Soil Till Res 39:229–239

Franzluebbers AJ, Hons FM, Zuberer DA (1995a) Tillage and crop effects on seasonal soil carbon and nitrogen dynamics. Soil Sci Soc Am J 59:1618–1624

Franzluebbers K, Weaver RW, Juo ASR, Franzluebbers AJ (1995b) Mineralization of carbon and nitrogen from cowpea leaves decomposing in soils with different levels of microbial biomass. Biol Fertil Soils 19:100–102

Franzluebbers AJ, Haney RL, Hons FM, Zuberer DA (1999) Assessing biological soil quality with chloroform fumigation-incubation: why subtract a control? Can J Soil Sci 79:521–528

Frey SD, Elliott ET, Paustian K (1999) Bacterial and fungal abundance and biomass inconventional and no-tillage agroecosystems along two climatic gradients. Soil Biol Biochem 31:573–585

Friebe B, Henke W (1991) Bodentiere und deren Strohabbauleistungen bei reduzierter Bodenbearbeitung. Z. f. Kulturtechnik und Landentwicklung 32:121–126

Frielinghaus M (2002) Soil erosion and pesticide translocation control. In: Pimental D (ed) Encyclopedia of pest management. CRC, New York, pp 777–780

Gál A, Vyn TJ, Michéli E, Kladivko EJ, Mcfee WW (2007) Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zone sampling depths. Soil Till Res 96:42–51

Galloway JN, Townsend AR, Erisman JW, Bekunda M, Cai ZC, Freney JR, Martinelli LA, Seitzinger SP, Sutton MA (2008) Transformation of the nitrogen cycle: recent trends, questions, and potential solutions. Science 320:889–892

Gerard BM, Hay RKM (1979) The effect on earthworms of plowing, tined cultivation, direct drilling and nitrogen in a barley monoculture system. J Agr Sci 93:147–155

Giannakopoulos C, Le Sager P, Bindi M, Moriondo M, Kostopoulou A, Goodess CM (2009) Climatic changes and associated impacts in the Mediterranean resulting from a 2 °C global warming. Glob Planet Change 68:209–224

Gicheru PT (1994) Effects of residue mulch and tillage on soil-moisture conservation. Soil Technol 7:209–220

Goddard T, Haugen-Kozyra K, Ridge A (2009) Conservation agriculture protocols for green house gas offsets in a working carbon market. Paper presented at the IV World Congress on Conservation Agriculture, 3–7 February 2009, New Delhi, India

Gómez JA, Giraldez JV, Fereres E (2005) Water erosion in olive orchards in Andalusia (Southern Spain): a review. Geophys Res Abst 7

Gotwald WH (1986) The beneficial economic role of ants. In: Vinson SB (ed) Economic impact and control of social insects. Praeger, New York, pp 290–313

Govaerts B, Sayre KD, Lichter K, Dendooven L, Deckers J (2007) Influence of permanent raised bed planting and residue management on physical and chemical soil quality in rain fed maize/wheat systems. Plant Soil 291:39–54

Grandy AS, Robertson GP, Thelen KD (2006) Do productivity and environmental trade-offs ustify periodically cultivating no-till cropping systems? Agron J 98:1377–1383

Greb BW (1966) Effect of surface-applied wheat straw on soil water losses by solar distillation. Soil Sci Soc Am Proc 30:786

Gregorich EG, Drur CF, Baldock JA (2001) Changes in soil carbon under long-term maize in monoculture and legume-based rotation. Can J Soil Sci 81:21–31

Gregorich EG, Rochette P, VandenBygaart AJ, Angers D (2005) Greenhouse gas contributions of agricultural soils and potential mitigation practices in Eastern Canada. Soil Till Res 81:53–72

Guggenberger G, Frey SD, Six J, Paustian K, Elliott ET (1999) Bacterial and fungal cellwall residues in conventional and no-tillage agroecosystems. Soil Sci Soc Am J 63:1188–1198

Haines PJ, Uren NC (1990) Effectsof conservation tillage farming on soil microbial biomass, organic matter and earthworm population, in north-eastern Victoria. Aust J Exp Agric 30:365–371

Hansen S, Maehlum JE, Bakken LR (1993) N_2O and CH_4 fluxes in soil influenced by fertilization and tractor traffic. Soil Biol Biochem 25:621–630

Hansen EM, Munkholm LJ, Melander B, Olesen JE (2010) Can non-inversion tillage and straw retainment reduce N leaching in cereal-based crop rotations? Soil Till Res 109:1–8

Harper D (1992) Eutrophication of fresh waters. Chapman & Hall, Saffolk, p 327

Harper LA (2005) Ammonia: measurement issues. In: Hatfield JL, Baker JM, Viney MK (eds) Micrometeorology in agricultural systems, Agronomy Monograph, vol 47. ASA, Madison, pp 345–379

Harrison PA, Butterfield R, Downing TE (1995) Climate change and agriculture in Europe: assessment of impacts and adaptations. Research Report No. 9, Environmental Change Unit, University of Oxford, pp 330–388

Hatfield JL, Sauer TJ, Prueger JH (2001) Managing soils to achieve greater water use efficiency: a review. Agric J 93:271–280

Havlin JL, Kissel DE, Maddux LD, Claassen MM, Long JH (1990) Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci Soc Am J 54:448–452

Hernanz JL, Lopez R, Navarrete L, Sanchez-Giron V (2002) Long-term effects of tillage systems and rotations on soil structural stability and organic carbon stratification in semiarid central Spain. Soil Till Res 66:129–141

Hernanz L, Sánchez-Girón V, Navarrete L (2009) Soil carbon sequestration and stratification in a cereal/leguminous crop rotation with three tillage systems in semiarid conditions. Agric Ecosyst Environ 133:114–122

Herrero EV, Mitchell JP, Lanini WT, Temple SR, Miyao EM, Morse RD, Campiglia E (2001) Soil properties change in no-till tomato production. Calif Agric 55:30–34

Holland JM, Reynolds CJM (2003) The impact of soil cultivation on arthropod (Coleoptera and Araneae) emergence on arable land. Pedobiologia 47:181–191

Holt JA, Robertson LN, Radford BJ (1993) Effects of tillage and stubble residue treatments on termite activity in 2 central Queensland vertosols. Aust J Soil Res 31:311–317

Horáček J, Ledvina R, Raus A (2001) The content of quality of organic matter in cambisol in a long-term no tillage system. Rostlinná Výroba 47:205–210

House GJ, Stinner BR (1983) Arthropods in no-tillage soybean agroecosystems—community composition and ecosystem interactions. Environ Manag 7:23–28

House GJ, Parmelee RW (1985) Comparison of soil arthropods and earthworms from conventional and no-tillage agroecosystems. Soil Till Res 5:351–360

Hu ZH, Ling H, Chen ST, Shen SH, Zhang H, Sun YY (2013) Soil respiration, nitrification, and denitrification in a wheat farmland soil under different managements. Commun Soil Sci Plant Anal 44:3092–3102

Huijsmans JFM, Hol JMG, Vermeulen GD (2003) Effect of application method, manure characteristics, weather and filed conditions on ammonia volatilization from manure applied to arable land. Atmos Environ 37:3669–3680

Hulme M, Osborn TJ, Johns TC (1998) Precipitation sensitivity to global warming: comparisons of observations with HadCM2 simulations. Geophys Res Lett 25:3379–3382

Hussain A, Mulholland BJ, Black CR, Taylor IB, Roberts JA (1999a) Novel approaches for examining the effects of differential soil compaction on xylem sap ABA concentration, stomatal conductance and growth in barley (*Hordeum vulgare* L.). Plant Cell Environ 22(11):1377–1388

Hussain I, Olson KR, Ebelhar SA (1999b) Long-term tillage effects on soil chemical properties and organic matter fractions. Soil Sci Soc Am J 63:1335–1341

Hütsch BW (1998) Tillage and land use effects on methane oxidation rates and their vertical profiles in soil. Biol Fertil Soils 27:284–292

Hütsch BW (2001) Methane oxidation, nitrification, and counts of methanotrophic bacteria in soils from a long-term fertilization experiment (“Ewiger Roggenbau”at Halle). J Plant Nutr Soil Sci 164:21–28

Hütsch BW, Webster CP, Powlson DS (1993) Long term effects of nitrogen fertilization on methane oxidation in soil of the broadbalk wheat experiment. Soil Biol Biochem 25:1307–1315

IPCC (2001) Climate Change 2001: The Scientific Basis. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds) Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 881

IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University , Cambridge, p 996

IPCC (2013) Climate Change 2013: The Physical Science Basis 2013

Jagtap V, Bhargava S, Streb P, Feierabend J (1998) Comparative effect of water, heat and light stresses on photosynthetic reactions in Sorghum bicolor (L.) Moench. J Exp Bot 49:1715–1721

Jarecki MK, Lal R (2003) Crop management for soil carbon sequestration. Crit Rev Plant Sci 22:471–502

Jiang Y, Huang B (2001) Drought and heat stress injury to two cool season turfgrasses in relation to antioxidant metabolism and lipid peroxidation. Crop Sci 41:436–442

Johnson AM, Hoyt GD (1999) Changes to the soil environment under conservation tillage. HortTechnology 9:380–393

Kassam A, Friedrich T, Shaxson F, Pretty J (2009) The spread of conservation agriculture: justification, sustainability and uptake. Int J Agric Sustainabil 7:292–320

Kassam A, Basch G, Friedrich T, Shaxson F, Goddard T, Amado T, Crabtree B, Hongwen L, Mello I, Pisante M, Mkomwa S (2013) Soil management is more than what and how crops are grown. In: Lal R, Stewart BA (eds) Principles of sustainable soil management in agroecosystems. Series: advances in soil sciences. CRC, Boca Raton, pp 338–387, ISBN: 978-1-4665-1346–4

Kay BD (1990) Rates of change of soil structure under different cropping systems. Adv Soil Sci 12:1–52

Kimball BA, Kobayashi K, Bindi M (2002) Responses of agricultural crops to free-air CO_2 enrichment. Advn Agron 77:293–368

Kirkby MJ, Jones RJA, Irvine B, Gobin A, Govers G, Cerdan O, Van Rompaey AJJ, Le Bissonnais Y, Daroussin J, King D, Montanarella L, Grimm M, Vieillefont V, Puigdefabregas J, Boer M, Kosmas C, Yassoglou N, Tsara M, Mantel S, Van Lynden G (2004) Pan-European soil erosion risk assessment: the PESERA Map, Version 1 October 2003. Explanation of special publication

Ispra 2004 No73 (S.P.I.04.73). European Soil Bureau Research Report No. 16, EUR 21176, 18 pp. and I map in ISO B1 format. Office for Official Publications of the European Communities, Luxembourg

Kladivko EJ (2001) Tillage systems and soil ecology. Soil Till Res 61:61–76

Kladivko EJ, Akhouri NM, Weesies G (1997) Earthworm populations and species distributions under no-till and conventional tillage in Indiana and Illinois. Soil Biol Biochem 29:613–615

Klein T, Holzkamper A, Calanca P, Seppelt R, Fuhrer J (2013) Adapting agricultural land management to climate change: a regional multi-objective optimization approach. Landscape Ecol 28:2029–2047

Knowles TA, Singh B (2003) Carbon storage in cotton soils of northern New South Wales. Aust J Soil Res 41:889–903

Kuzyakov Y, Friedel JK, Stahr K (2000) Review of mechanisms and quantification of priming effects. Soil Biol Biochem 32:1485–1498

Laflen JM, Roose EJ (1998) Methodologies for assessment of soil degradation due to water erosion. In: Lal etal (eds) Methods for assessment of soil degradation: advances in soil science. CRC, Boca Raton, pp 31–55

Lafond GP, Walley F, Schoenau J, May WE, Holzapfel CB, McKell J, Halford J (2008) Long-term vs. short-term conservation tillage: 28-43. In: Proceedings of the 20th annual meeting and conference of the Saskatchewan Soil Conservation Association, Regina, Saskatchewan, 12–13 February

Lal R, Follett RF, Stewart BA, Kimble JM (2007) Soil carbon sequestration to mitigate climate change and advance food security. Soil Sci 172(12):943–956

Lampurlanés J, Cantero-Martınez C (2006) Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions. Soil Till Res 5:13–26

Le Mer J, Roger P (2001) Production, oxidation, emission and consumption of methane by soils: a review. Eur J Soil Biol 37:25–50

Lessard R, Rochette P, Topp GC, Pattey E, Desjardins RL (1994) Methane and carbon dioxide fluxes from poorly drained adjacent cultivated and forest sites. Can J Soil Sci 74:139–146

Levy PE, Burden A, Cooper MDA, Dinsmore KJ, Drewer J, Evans C, Fowler D, Gaiawyn J, Gray A, Jones SK, Jones T, McNamara NP, Mills R, Ostle N, Sheppard LJ, Skiba U, Sowerby A, Ward SE, Zielinskli P (2012) Methane emissions from soils: synthesis and analysis of a large UK data set. Glob Change Biol 18:1657–1669

Li HW, Gao HW, Wu HD, Li WY, Wang XY, He J (2007) Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. Aust J Soil Res 45:344–350

Linn DM, Doran JW (1984) Aerobic and anaerobic microbial populations in no-till and plowed soils. Soil Sci Soc Am J 48:794–799

Lobb D, Lindstrom MJ (1999) Tillage translocation and tillage erosion. Poster Presentation at Manitoba Soil Science Society Meeting Winnipeg, Manitoba, vol 75, pp 211–218, 1–2 February 1999

Lobb D, Kachanoski RG, Miller MH (1995) Tillage translocation and tillage erosion on shoulder slope landscape positions measured using 137Cs as a tracer. Can J Soil Sci 75:211–218

Lobell DB, Field CB (2007) Global scale climate-crop yield relationships and the impacts of recent warming. Environ Res Lett 2

López MV, Arrue JL (2005) Soil tillage and wind erosion in fallow lands of Central Aragaon, Spain: an overview. In: Faz A, Ortiz R, Mermut AR (eds) Sustainable use management of soils: arid semiarid regions Advances in Geo Ecology, vol 36. Catena, Reiskirchen, 93–102

Lopez MV, Gracia R, Arrue JL (2001) An evaluation of wind erosion hazards in fallow lands of semiarid Aragon (NE Spain). J Soil Water Conserv 56:212–219

López-Bellido RJ, Fontán JM, López-Bellido FJ, López-Bellido L (2010) Carbon sequestration by tillage, rotation, and nitrogen fertilization in a mediterranean vertisol. Agron J 102:310–318

Lopez-Fando C, Pardo MT (2001) The impact of tillage systems and crop rotations on carbon sequestration in calcic luvisol of central Spain. I World Congress on Conservation Agriculture. Madrid, 1–5 October

López-Fando C, Dorado J, Pardo MT (2007) Effects of zone-tillage in rotation with no-tillage on soil properties and crop yields in a semiarid soil from central Spain. Soil Till Res 95:266–276

Lupwayi NZ, Monreal MA, Clayton GW, Grant CA, Johnston AM, Rice WA (2001) Soil microbial biomass and diversity respond to tillage and sulphur fertilizers. Can J Soil Sci 81:577–589

Magdoff F, Weil RR (2004) Soil organic matter management strategies. In: Magdoff F, Weil RR (eds) Soil organic matter in sustainable agriculture. CRC, New York, pp 45–65

Mando A, Miedema R (1997) Termite-induced change in soil structure after mulching degraded (crusted) soil in the Sahel. Appl Soil Ecol 6:241–249

Marasas ME, Sarandon SJ, Cicchino AC (2001) Changes in soil arthropod functional group in a wheat crop under conventional and no tillage systems in Argentina. Appl Soil Ecol 18:61–68

Mele PM, Carter MR (1999) Impact of crop management factors in conservation tillage farming on earthworm density, age structure and species abundance in south-eastern Australia. Soil Till Res 50:1–10

Mitchell CC, Arriaga FJ, Entry JA, Novak JL, Goodman WR, Reeves DW, Runge MW, Traxler GJ (1996) The Old Rotation, 1896–1996 100 Years of Sustainable Cropping Research. Alabama Agricultural Experiment Station, Auburn, AL.z<1

Miyazawa K, Tsuji H, Yamagata M, Nakano H, Nakamoto T (2002) The effects of cropping systems and fallow managements on microarthropod populations. Plant Prod Sci 5:257–265

Mojeremane W, Rees RM, Mencuccini M (2011) The effects of site preparation practices on carbon dioxide methane and nitrous oxide fluxes from a peaty gley soil. Forestry 19:1–15

Montzka SA, Dlugokencky EJ, Butler JH (2011) Non-CO_2 greenhouse gases and climate change. Nature 476:43–50

Moreno F, Murillo JM, Pelegrín F, Girón IF (2006) Long-term impact of conservation tillage on stratification ratio of soil organic carbon and loss of total and active $CaCO_3$. Soil Till Res 85:86–93

Moretto AS, Distel RA, Didone NG (2001) Decomposition and nutrient dynamic of leaf litter and roots from palatable and unpalatable grasses in a semiarid grassland. Appl Soil Ecol 18:31–37

Moriondo M, Bindi M, Kundzewicz ZW, Szwed M, Chorynski A, Matczak P et al (2010) Impact and adaptation opportunities for European agriculture in response to climatic change and variability. Mitig Adapt Strateg Glob Change 15:657–679

Mrabet R (2008) No-tillage systems for sustainable dryland agriculture in Morocco. Institut National de la Recherche Agronomique, Tangier

Mrabet R, Saber N, El-Brahli A, Lahlou S, Bessam F (2001) Total particulate organic matter and structural stability of a calcixeroll soil under different wheat rotations and tillage systems in a semiarid area of Morocco. Soil Till Res 57:225–235

Mudge F, Adger WN (1995) Methane fluxes from artificial wetlands: a global appraisal. Environ Manag 19:39–55

Mupangwa W, Twomlow S, Walker S, Hove L (2007) Effect of minimum tillage and mulching on maize (Zea mays L.) yield and water content of clayey and sandy soils. Phys Chem Earth 32:1127–1134

Nesbit SP, Breitenbeck GA (1992) A laboratory study of factors influencing methane uptake by soils. Agric Ecosyst Environ 41:39–54

Neue HU (1997) Fluxes of methane from rice fields and potential for mitigation. Soil Use Manag 13:258–267

Newcombe CP, Macdonald DD (1991) Effects of suspended sediments on aquatic ecosystems. N Am J Fisheries Manag 11(1):72–82

Nisbet MC (2009) Communicating climate change: why frames matter for public engagement. Environ Sci Policy Sustain Develop 51(2):12–23

Nkem JN, de Bruyn LAL, Grant CD, Hulugalle NR (2000) The impact of ant bioturbation and foraging activities on surrounding soil properties. Pedobiologia 44:609–621

Nouchi I, Hosono T, Aoki K, Minami K (2010) Seasonal variation in methane flux from rice paddies associated with methane concentration in soil water, rice biomass and temperature, and its modeling. Plant Soil 161:195–208

Novak SM, Fiorelli JL (2010) Greenhouse gases and ammonia emission from organic mixed crop—dairy systems: a critical review of mitigation options. Agron Sustain Dev 30:215–236

Nuutinen V (1992) Earthworm community response to tillage and residue management on different soil types in Southern Finland. Soil Till Res 23:221–239

OECD (2009) The organisation for economic co-operation and development (OECD) annual report. OECD Publ., Paris

OECD (2011) Fostering productivity and competitiveness in agriculture. OECD, Paris

Olesen JE, Trnka M, Kersebaum KC, Skjelvåg AO, Seguin B, Peltonen-Sainio P et al (2011) Impacts and adaptation of European crop production systems to climate change. Eur J Agron 34:96–112

Olesen JE, Børgensen CD, Elsgaard L, Palosuo T, Rötter R, Skjelvåg AO (2012) Changes in time of sowing, flowering and maturity of cereals in Europe under climate change. Food Addit Contam A 29(10):1527–1542

Owens LB, Malone RW, Hothem DL, Starr GC, Lal R (2002) Sediment carbon concentration and transport from small watersheds under various conservation tillage. Soil Till Res 67:65–73

Palm C, Blanco-Canqui H, De Clerck F, Gatere L, Grace P (2013) Conservation agriculture and ecosystem services: an overview. Agric Ecosyst Environ 187:87–105

Papendick RI, Lindstro MJ, Cochran VL (1973) Soil mulch effects on seedbed temperature and water during fallow in Eastern Washington. Soil Sci Soc Am J 37:307–314

Parmesan C (2006) Ecological and evolutionary responses to recent climate change. Annu Rev Ecol Evol Syst 37:637–669

Pelster DE, Chantigny MH, Rochette P, Angers DA, Laganière J, Zebarth B, Goyer C (2013) L̓apport de résidus de culture au sol modifie les émissions de protoxyde d̓azote induites par les cycles gel-dégel. Can J Soil Sci 93:415–425

Peltonen-Sainio P, Jauhiainen L, Hakala K, Ojanen H (2009) Climate change and prolongation of growing season: changes in regional potential for field crop production in Finland. Agric Food Sci 18:171–190

Perego A, Basile A, Bonfante A, De Mascellis R, Terribile F, Brenna S, Acutis M (2012) Nitrate leaching under maize cropping systems in Po Valley (Italy). Agric Ecosyst Environ 47:57–65

Phillips FA, Leuning R, Baigent R, Kelly KB, Denmead OT (2007) Nitrous oxide flux measurements from an intensively managed irrigated pasture using micrometeorological techniques. Agric For Meteorol 143:92–105

Pinheiro EFM, Pereira MG, Anjos LHC (2004) Aggregate distribution and soil organic matter under different tillage systems for vegetable crops in a Red Latosol from Brazil. Soil Till Res 77:79–84

Pisante M (2002) Tecniche agronomiche conservative per la riduzione dei processi di degradazione del suolo. Atti convegno nazionale "Desertificazione: la nuova emergenza del bacino del mediterraneo", Catania-Caltagirone-Palermo, 22–25 maggio 2001, pp 3–9

Pisante M, Corsi S, Amir K, Friedrich T (2010) The challenge of agricultural sustainability for Asia and Europe. Transit Stud Rev 17(4):662–667. doi:10.1007/s11300-010-0181-z

Pisante M, Stagnari F, Grant C (2012) Agricultural innovations for sustainable crop production intensification. Ital J Agron 7(4):300–311

Prasad PVV, Boote KJ, Allen LH (2006a) Adverse high temperature effects on pollen viability, seed-set, grain yield and harvest index of grain sorghum [Sorghum bicolor (L.) Moench] are more severe at elevated carbon dioxide due to higher tissue temperatures. Agric For Meteorol 139:237–251

Prasad PVV, Boote KJ, Allen LH, Sheehy JE, Thomas JMG (2006b) Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. Field Crops Res 95:398–411

Prasad PVV, Staggenborg SA (2008) Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. In: Ajuha LR, Reddy VR, Saseendran SA, Yu Q (eds) Response of crops to limited water: understanding and modeling water stress effects on plant growth processes. American Society of Agronomy, Madison, pp 301–356

Puget P, Chenu C, Balesdent J (1995) Total and young organic matter distributions in aggregates of silty cultivated soils. Eur J Soil Sci 46:449–459

Qaderi MM, Reid DM (2005) Growth and physiological responses of canola (*Brassica napus*) to UV-B and CO_2 under controlled environment conditions. Physiol Plant 125:247–259

Quine TA, Walling DE (1993) Use of caesium—137 measurements to investigate relationships between erosion rates and topography. In: Thomas DSG, Allison RJ (eds) Landscape sensitivity. Wiley, Chichester, pp 31–48

Rao KPC, Steenhuis TS, Cogle AL, Srinivasan ST, Yule DF, Smith GD (1998) Rainfall infiltration and runoff from an Alfisol in semiarid tropical India. I. No-till systems. Soil Till Res 48:51–59

Raper RL, Reeves DW, Schwab EB, Burmester CH (2000) Reducing soil compaction of Tennessee Valley soils in conservation tillage systems. J Cotton Sci 4(2):84–90

Rasmussen KJ (1999) Impact of ploughless soil tillage on yield and soil quality: a Scandinavian review. Soil Till Res 53:3–14

Reeleder RD, Miller JJ, Coelho BRB, Roy RC (2006) Impacts of tillage, cover crop, and nitrogen on populations of earthworms, microarthropods, and soil fungi in a cultivated fragile soil. Appl Soil Ecol 33:243–257

Regina K, Alakukku L (2010) Greenhouse gas fluxes in varying soil types under conventional and no-tillage practices. Soil Till Res 109:144–152

Reicosky DC (1997) Tillage-induced CO_2 emissions from soil. Nutr Cycl Agroesyst 49:273–285

Reicosky DC (1998) Effect of Tillage on the release of CO_2. Paper presented to the Symposium "Conservation Tillage: can it assist in mitigating the Greenhouse Gas Problem?". The University of Queensland

Reicosky DC, Lindstrom MJ (1993) Fall tillage methods: effect on short-term carbon dioxide flux from soil. Agron J 85-6:1237–1243

Reicosky DC, Lindstrom MJ (1995) Impact of fall tillage and short-term carbon dioxide flux. In: Lal R, Kimble J, Levine E, Stewart B (eds) Soil Global Change. Lewis , Chelsea, pp 177–187

Reicosky DC, Lindstrom MJ, Schumacher TE, Lobb D, Malo DD (2005) Tillage-induced CO_2 loss across an eroded landscape. Soil Till Res 81(2):183–194

Rhoton FE, Shipitalo MJ, Lindbo DL (2002) Runoff and soil loss from midwestern and southeastern US silt loam soils as affected by tillage practice and soil organic matter content. Soil Till Res 66:1–11

Riley HCF, Bleken MA, Abrahamsen S, Bergjord AK, Bakken AK (2005) Effects of alternative tillage systems on soil quality and yield of spring cereals on silty clay loam and sandy loam soils in the cool, wet climate of central Norway. Soil Till Res 80:79–93

Rizhsky LH, Liang H, Shuman J, Shulaev V, Davletova S, Mittler R (2004) When defense pathways collide: the response of Arabidopsis to a combination of drought and heat stress. Plant Physiol 134:1683–1696

Robertson LN, Kettle BA, Simpson GB (1994) The influence of tillage practices on soil macrofauna in a semiarid agroecosystem in Northeastern Australia. Agric Ecosyst Environ 48:149–156

Robertson GP, Bruulsema TW, Gehl RJ, Kanter D, Mauzerall DL, Rotz CA, Williams CO (2012) Nitrogen-climate interactions in US agriculture. Biogeochemistry 114:41–70

Robinson CA, Cruse RM, Ghaffarzadeh M (1996) Cropping system and nitrogen effects on Mollisol organic carbon. Soil Sci Soc Am J 60:264–269

Rochette P (2008) No-till only increases N_2O emissions in poorly-aerated soils. Soil Till Res 101:97–100

Rochette P, Janzen HH (2005) Towards a revised coefficient for estimating N_2O emissions from legumes. Nutr Cycl Agroecosyst 73:171–179

Rochette P, Angers DA, Chantigny MH, Bertrand N (2008) N_2O emissions respond differently to no-till in a loam and a heavy clay soil. Soil Sci Soc Am J 72:1363–1369

Röhrig R, Langmaack M, Schrader S, Larink O (1998) Tillage systems and soil compaction: their impact on abundance and vertical distribution of Enchytraeidae. Soil Till Res 46:117–127

Roth CH, Meyer B, Frede HG, Derpsch R (1988) Effect of mulch rates and tillage systems on infiltrability and other soil physical-properties of an oxisol in Parana, Brazil. Soil Till Res 11:81–91

Rötter RP, Palosuo T, Pirttioja NK, Dubrovski M, Salo T, Fronzek S, Aikasalo R, Trnka M, Ristolainen A, Carter TR (2011) What would happen to barley production in Finland if global warming exceeded 4°C? A model-based assessment. Eur J Agron 35:205–214

Rovira AD, Smettem KRJ, Lee KE (1987) Effect of rotation and conservation tillage on earthworms in a red-brown earth under wheat. Aust J Agric Res 38:829–834

Sauer TJ, Hatfield JL, Prueger JH (1996) Corn residue age and placement effects on evaporation and soil thermal regime. Soil Sci Soc Am J 60:1558–1564

Sauer TJ, Hatfield JL, Prueger JH (1997) Over-winter changes in radiant energy exchange of a corn residue-covered surface. Agric Forest Meteorol 85:279–287

Schütz H, Holzapfel-Pschorn A, Conrad R, Rennenberg H, Seiler W (1989) A three years continuous record on the influence of daytime, season and fertilizer treatment on methane emission rates from an Italian rice paddy field. J Geophys Res 94:16405–16416

Seghers D, Top EM, Reheul D, Bulcke R, Boeckx P, Verstraete W, Siciliano SD (2003) Long-term effects of mineral versus organic fertilizers on activity and structure of the methanotrophic community in agricultural soils. Environ Microbiol 5:867–877

Seinfeld JH, Pandis SN (2006) Atmospheric chemistry and physics: from air pollution to climate change. Wiley, New York, pp 1–1203

Sidiras N, Pavan MA (1985) Influencia do sistema de manejo do solo no seu nivel de fertilidade. Rev Bras Cienc Solo 9:244–254

Sisti CPJ, dos Santos HP, Kohhann R, Alves BJR, Urquiaga S, Boddey RM (2004) Change in carbon and nitrogen stocks in soil under 13 years of conventional or zero tillage in southern Brazil. Soil Till Res 76:39–58

Six J, Elliot ET, Paustian K, Doran JW (1998) Aggregation and soil organic matter accumulation in cultivated and native grassland soils. Soil Sci Soc Am J 62:1367–1377

Six J, Ogle SM, Breidt FJ, Conant RT, Mosier AR, Paustian K (2004) The potential to mitigate global warming no-tillage management is only realized when practiced in the long run. Global Change Biol 10:155–160

Skjøth CA, Geels C (2013) The effect of climate and climate change on ammonia emissions in Europe. Atmos Chem Phys 13:117–128

Smith P, Olesen JE (2010) Synergies between the mitigation of, and adaptation to, climate change in agriculture. J Agric Sci 148:543–552

Smith P, Powlson DS, Glendenning MJ, Smith JU (1998) Preliminary estimates of the potential for carbon mitigation in European soils through no-till farming. Global Change Biol 4:679–685

Smith P, Goulding KW, Smith KA, Powlson DS, Smith JU, Falloon P, Coleman K (2001) Enhancing the carbon sink in European agricultural soils: including trace gas fluxes in estimates of carbon mitigation potential. Nutr Cycl Agroecosyst 60:237–252

Soane BD, Ball BC, Arvidsson J, Basch G, Moreno F, Roger-Estrade J (2012) No-till in northern, western and south-western Europe: a review of problems and opportunities for crop production and the environment. Soil Till Res 118:66–87

Sommer SG, Hutchings NJ (2001) Ammonia emission from field applied manure and its reduction—invited paper. Eur J Agron 15:1–15

Sommer SG, Schjoerring JK, Denmead OT (2004) Ammonia emission from mineral fertilizers and fertilized crops. Adv Agron 82:558–622

Soussana JF, Lüscher A (2007) Temperate grasslands and the global atmospheric change: a review. Grass Forage Sci 62:127–134

Southworth J, Randolph JC, Habeck M, Doering OC, Pfeifer RA, Rao DG et al (2000) Consequences of future climate change and changing climate variability on maize yields in the midwestern United States. Agric Ecosyst Environ 82:139–158

Spedding TA, Hamel C, Mehuys GR, Madramootoo CA (2004) Soil microbial dynamics in maize-growing soil under different tillage and residue management systems. Soil Biol Biochem 36:499–512

Springett JA (1992) Distribution of lumbricid earthworms in New Zealand. Soil Biol Biochem 24:1377–1381

Stagnari F, Ramazzotti S, Pisante M (2009) Conservation agriculture: a different approach for crop production through sustainable soil and water management: a review. Agronomy for sustainable development. In: Lichtfouse E (ed) Organic farming, pest control and remediation of soil pollutants, sustainable agriculture reviews 1. Springer, New York, pp 55–83. doi:10.1007/978-1-4020-9654-9

Stahl PD, Parkin TB, Christensen M (1999) Fungal presence in paired cultivated and uncultivated soils in central Iowa, USA. Biol Fertil Soils 29:92–97

Steiner JL (1989) Tillage and surface residue effects on evaporation from soils. Soil Sci Soc Am J 53:911–916

Stinner BR, House GJ (1990) Arthropods and other invertebrates in conservation-tillage agriculture. Annu Rev Entomol 35:299–318

Stockfisch N, Forstreuter T, Ehlers W (1999) Ploughing effects on soil organic matter after twenty years of conservation tillage in Lower Saxony, Germany. Soil Till Res 52:91–101

Stuart M, Gooddy D, Bloomfield J, Williams A (2011) A review of the impact of climate change on future nitrate concentrations in groundwater of the UK. Sci Total Environ 409(15):2859–2873

Sudhishri S, Dass A, Lenka NK (2008) Efficacy of vegetative barriers for rehabilitation of degraded hill slopes in eastern India. Soil Till Res 99:98–107

Supit I, Van Diepen CA, De Wit AJW, Kabat P, Baruth B, Ludwig F (2010) Recent changes in the climatic yield potential of various crops in. Europe Agric Syst 103:683–694

Sutton M (2006) Scope and overview of the UNECE Expert Workshop on Ammonia. C. E. H. Clean Air, December, Edinburgh, pp 1–8

Tebrügge F (2001) No-tillage visions-protection of soil, water and climate and influence on management and farm income. Garcia-Torres L Benites J Martınez-Vilela A (eds) Conservation agriculture-a worldwide challenge World Congress on Conservation Agriculture 1:303–316

Tebrügge F (2000) No-tillage visions—protection of soil, water and climate. Justus-Liebig University, Giessen

Tebrügge F, During RA (1999) Reducing tillage intensity—a review of results from a long-term study in Germany. Soil Till Res 53:15–28

Terman GL (1979) Volatilization of nitrogen as ammonia from surface applied fertilizers, organic amendments and crop residues. Agron J 31:189–223

Thierfelder E, Amézquita C, Stahr K (2005) Effects of intensifying organic manuring and tillage practices on penetration resistance and infiltration rate. Soil Till Res 82(2):211–226

Tolk JA, Howell TA, Evett SR (1999) Effect of mulch, irrigation, and soil type on water use and yield of maize. Soil Till Res 50:137–147

Tubiello FN, Amthor JS, Boote KJ, Donatelli M, Easterling W, Fischer G et al (2007) Crop response to elevated CO_2 and world food supply. A comment on 'Food for Thought… ' by Long et al. Science 312, 1918–1921. Eur J Agron 26:215–233

Unger PW (1991) Organic-matter, nutrient, and ph distribution in no-tillage and conventional-tillage semiarid soils. Agric J 83:186–189

Unger PW, Parker JJ (1976) Evaporation reduction from soil with wheat, sorghum, and cotton residues. Soil Sci Soc Am J 40:938–942

Uri ND, Atwood JD, Sanabria J (1998) The environmental benefits and costs of conservation tillage. Sci Total Environ 216:13–32

Ussiri DAN, Lal R, Jarecki MK (2009) Nitrous oxide and methane emissions from long-term tillage under a continuous corn cropping system in Ohio. Soil Till Res 104:247–255

Van derMJ, Van Faassen HG, Vertregt N, Bussink W, Den Boer DJ (1989) Ammonia emissions from arable and grassland soils. In: Hansen JA, Hendricksen K (eds) Nitrogen in organic wastes applied to soil. Academic, Waltham, pp 185–201

Van DBosscheA, De Bolle S, De Neve S, Hofman G (2009) Effect of tillage intensity on N mineralization of different crop residues in a temperate climate. Soil Till Res 103:316–324

Van denHRN, Bakker SE, Jetten MSM, Hefting MM (2011) Decreased N_2O reduction by low soil pH causes high N_2O emissions in a riparian ecosystem. Geobiology 9:294–300

Van Groenigen JW, Oenema O, Van Groenigen KJ, Velthof G, Van Kessel C (2011) Best nitrogen management practices to decrease greenhouse gas emissions. Better Crops 95(2):16–17

Van Kessel C, Farrell RE, Roskoski JP (1994) Recycling of the naturally-occurring 15 N in an established stand of Leucaena leucocephala. Soil Biol Biochem 26:757–762

Van Kessel C, Venterea R, Ix JS, Adviento-Borbe MA, Linquist B, van Groenige KJ (2013) Climate, duration, and N placement determine N_2O emissions in reduced tillage systems: a meta-analysis. Global Change Biol 19:33–44

Van den Bygaart AJ, Yang XM, Kay BD, Aspinall JD (2002) Variability in carbon sequestration potential in no-till soil landscapes of southern Ontario. Soil Till Res 65(2):231–241

Van den Bygaart AJ, Gregorich EG, Angers DA (2003) Influence of agricultural management on soil organic carbon: a compendium and assessment of Canadian studies. Can J Soil Sci 83:363–380

Venterea RT, Dolan MS, Ochsner TE (2010) Urea decreases nitrous oxide emissions compared with anhydrous ammonia in a Minnesota corn cropping system. Soil Sci Soc Am J 74:407–418

Wanniarachchi SD, Voroney RP, Vyn TJ, Beyaert RP, MacKenzie AF (1999) Tillage effects on the dynamics of total and corn-residue-derived soil organic matter in two southern Ontario soils. Can J Soil Sci 79:473–480

Wardle DA (1995) Impacts of disturbance on detritus food webs in agro-ecosystems of contrasting tillage and weed management practices. In: Begon M, Fitter AH (eds) Advances in ecological research. Academic, New York, pp 105–185

Wassmann R, Wang MX, Shangguan XJ, Xie XL, Shen RX, Wang YS, Papen H, Rennenberg H, Seiler W (1993) First records of a field experiment on fertilizer effects on methane emission from rice fields in Hunan-province (PR China). Geophys Res Lett 20:2071–2074

Webb J, Pain B, Bittman S, Morgan J (2010) The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response-A review. Agric Ecosyst Environ 137:39–46

West TO, Post WM (2002) Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Sci Soc Am J 66(6):1930–1946

Wheeler TR, Ellis RH, Hadley P, Morison JIL, Batts GR, Daymond AJ (1996) Assessing the effects of climate change on field crop production. Aspects Appl Biol 45:49–54

Whitbread AM, Lefroy RDB, Blair GJ (1998) A survey of the impact of cropping on soil physical and chemical properties in north-western New South Wales. Aust J Soil Res 36:669–681

Wuebbles DJ, Hayhoe K (2002) Atmospheric methane and global change. Earth Sci Rev 57:177–221

Wuest SB (2001) Earthworm, infiltration, and tillage relationships in a dryland pea-wheat rotation. Appl Soil Ecol 18:187–192

Wyss E, Glasstetter M (1992) Tillage treatments and earthworm distribution in a swiss experimental corn field. Soil Biol Biochem 24:1635–1639

Xu H, Cai ZC, Tsuruta H (2003) Soil moisture between rice-growing seasons affects methane emission, production, and oxidation. Soil Sci Soc Am J 67:1147–1157

Xu L, Penner JE (2012) Global simulations of nitrate and ammonium aerosols and their radiative effects. Atmos Chem Phys 12:9479–9504

Yang SS, Chang HL (2001) Methane emission from paddy fields in Taiwan. Biol Fertil Soils 33:157–165

Yang XM, Kay BD (2001) Impacts of tillage practices on total, loose- and occluded-particulate, and humified organic carbon fractions in soils within a field in southern Ontario. Can J Soil Sci 81:149–156

Yano T, Aydin M, Haraguchi T (2007) Impact of climate change on irrigation demand and crop growth in a Mediterranean environment of Turkey. Sensors 7:2297–2315

Zavattaro L, Monaco S, Sacco D, Grignani C (2012) Options to reduce N loss from maize in intensive cropping systems. Agric Ecosyst Environ 147:24–35

Zhao M, Running SW (2010) Drought-induced reduction in global terrestrial net primary production from 2000 through 2009. Science 329:940–943

Zunino M (1991) Food relocation behaviour: a multivalent strategy of Coleoptera. In: Zunino M, Bellés X, Blas M (eds) Advances in coleopterology. AEC, Barcelona, pp 297–313