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Review

Terrestrial ecosystem functioning affected by agricultural management systems: A review

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ABSTRACT

With increasing world population, there is an evident pressure on food production demand at the expense of environment. Maximizing yields at environmental cost is quite high especially in terms of soil and water deterioration. Traditional/conventional agricultural system is complemented with intensive tillage, mono-cropping and inappropriate crop residue management with deleterious impacts on the environment. Such agricultural practices have substantially contributed to climate change due to resulting greenhouse gases (GHGs) emissions. In recent decades, "conservation agriculture", is being adopted which employs no or minimum tillage, diversified crop rotation and efficient crop residues management. Such approaches are associated to the decreased GHGs emissions due to low consumption of fossil fuels and fertilizers (especially N_2O emissions from nitrogenous fertilizers). However, increased use of pesticides in conservation agriculture can be an important threat to the environment. This review collates impacts of both agricultural management systems on terrestrial ecosystem functioning in terms of soil quality and environmental sustainability. Impacts of conventional and conservation systems on soil health, carbon sequestration, GHGs emissions, cropping patterns, weed dynamics and environmental degradation are critically evaluated and research gaps are highlighted. Future research directions have been identified to promote the research regarding sustainable agriculture development.

1. Introduction

Substantial increase in future food demand requires increased yield of agricultural crops which must be sustainable to conserve environment and minimize the impact of climate change. Sustainable agriculture demands reduced GHGs emissions, less pesticides use, and low/no nutrient drift from the system, especially of nitrogen and phosphorus (Aune, 2012). Agricultural systems are comprised of multidimensional components and drivers that interact in complex ways to influence production sustainability (Walters et al., 2016). Currently, conventional system encompasses intensive tillage to manipulate the soil physical properties and to control weeds (Alam et al., 2014), mono-cropping, and limited recycling of materials (Aune, 2012).

On the other hand, conservation agriculture (CA), characterized by minimal soil disturbance with no or minimum tillage, diversified crop rotation, permanent soil cover and weed management is being promoted as a sustainable way of crop production (FAO, 2018). This, CA, may contribute towards several ecosystem services including climate change mitigation by minimizing GHGs emissions, carbon (C) sequestration, internal regulation of water and nutrients by altering soil physical, chemical and/or biological properties (Alikhani et al., 2018). About half of the global C emission is absorbed by natural sinks *i.e.* ocean and land (Le Quéré et al., 2015), therefore, suitable strategies are needed to increase capacity of the natural carbon sinks in the terrestrial biosphere to reduce the net accumulation of carbon (as CO_2) in the atmosphere (Lal, 2008). The Dust Bowl, a period of severe dust storms in the USA in 1930s, eroded large soil profile and badly impacted the crop production, is linked with the history of CA (Friedrich et al., 2012), which is now gaining popularity across the continents (Derpsch and Friedrich, 2009). Although, previous studies indicated that both conventional and conservation systems may result in approximately similar yields (Pimentel et al., 2005) or lower crop yields in CA but these systems can have different impacts on natural resources (Seufert et al., 2012). Thus, it is imperative to understand the impact of such

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systems on the environment, especially soil health and system sustainability.

In recent literature, many studies covering conventional and conservation agriculture (Farooq and Nawaz, 2014; Sihi et al., 2017) have been reported, but the information is limited, and it does not cover all possible impacts on the environment. This is the first review which covers the contrasting impacts of both agricultural management systems *i.e.* conventional and conservation agriculture, on terrestrial ecosystem functioning. Impacts of conventional and conservation systems on (i) soil health (aggregate stability and water infiltration, bulk density and rooting depth, nutrient dynamics and microbial activity) (ii) carbon sequestration and GHGs emissions, (iii) cropping patterns and weed dynamics, and (iv) environmental degradation (soil and water pollution), are critically summarized with focus on sustaining the agro-ecosystems.

2. Soil health

Historically, the Earth in temperate regions was covered by forests and grasslands, and with time, accessible lands had been used for crop production. Whereas less fertile and/or inaccessible lands such as hills or slopes remained forested (Quesada et al., 2010). The intensive use of soils affected the soil health directly or indirectly. Soil health is the ability of soil to sustain and support vital living ecosystem functions related to plants, animals and humans (Singh et al., 2011). In an agricultural system, the soil health is dependent on carbon transformations, nutrient cycles, soil structure, and pesticides dynamics. Intensive agricultural practices cause soil erosion affecting aggregate stability, carbon loss, nutrient depletion and microbial alterations by exposing the soils to precipitation, temperature variations and air (Sihi et al., 2017). Other soil properties such as water infiltration, bulk density, rooting depth *etc.* in the soil are mostly dependent on the aggregate stability. In conservation agriculture, the soil health issues are better managed to sustain the agricultural productions, considering them the greatest environmental threats to modern agriculture (Musinguzi et al., 2015; Mwango et al., 2016). Among conservation practices no till (NT) has impressive impacts on soil health in comparison to plough till (PT) which have been listed considering soil physical, chemical and biological health (Table 1).

2.1. *Aggregate stability and water infiltration*

Soil aggregate stability is an important physical property which leads to improved soil structure and ultimately, helps in improving the soil consistency and sustainability. Crop type, crop rotation, cover crops, residue management, tillage intensity, salt accumulation, and surface roughness play a significant role for aggregate stability (Horwath, 2008). The conventional tillage practices significantly change the soil physico-chemical properties as well as biogeochemical cycling. Conventional tillage practices often include deep ploughing and disc harrowing, which not only provide a good condition for seed germination but also increase the nutrient availability to plants, stimulating the mineralization and suppressing the denitrification processes (Pajares and Bohannan, 2016), while conservation agriculture strategies may improve soil aggregation and their stability (Shu et al., 2015).

Greater and diverse population of microbes may contribute towards soil aggregate stability due to the excretion of various compounds into the soil (Aislabie et al., 2013) by altering the other soil metabolic characteristics. However strong structural differences in microbial populations do not necessarily affect the aggregate stability (Büks et al., 2016). Physical stabilization of fungal hyphae and filamentous bacteria, and physico-chemical interactions of organic particles/exudates with mineral particles play key role to enhance the aggregate stability of soil (Büks et al., 2016). Furthermore, microbes develop biofilms with enhanced adhesion to soil surface, especially under unpleasant ecological conditions, through excretion of extracellular polymeric substance such as polysaccharides, proteins, lipids and humic substances (Büks et al., 2016; Ozturk and Aslim, 2010).

In conservation agriculture, cover crops protect the soils from erosion (Chou et al., 2015). Similarly, perennial and deep root system crops add more soil organic matter (SOM) to soil and less soil disruption, resulting in improved soil aggregation. While, conventional tillage results in rapid decomposition of organic matter, losing carbon as CO_2

Table 1

A summary of studies comparing soil properties under conventional and conservation production systems.

Soil properties	Crop rotation	NT	PT	Study duration	Reference
Aggregate stability (index)	lupins-maize-oats-soybean-wheat-soybean	41.1	26.8	7 years	FAO (2001)
Mean diameter of aggregate (mm)	wheat-soybean-wheat-soybean- wheat-soybean	1.8	1.6	7 years	FAO (2001)
Mean organic matter (%)	–	3.1	2.5	10 years	FAO (2001)
No. of worms/m^2	–	27.6	3.2	–	FAO (2001)
Soil losses (t/ha/year)	wheat-soybean rotation	3.3	26.4	12 years	Saturnino and Landers (1997)
Runoff losses (mm/ha/year)	wheat-soybean rotation	225	666	12 years	Saturnino and Landers (1997)
Soil losses (t/ha/year)	maize/soybean rotation	0.6	2.14	4 years	Saturnino and Landers (1997)
Total soil nitrogen (g kg^{-1})	rice-wheat rotation	0.33	0.27	3 years	(Nawaz et al., 2017)
Total soil porosity (%)	rice-wheat rotation	46.9	44.3	3 years	(Nawaz et al., 2017)
Soil microbial biomass carbon (μg g^{-1})	rice-wheat rotation	169	156	3 years	(Nawaz et al., 2017)
Total soil organic carbon (g kg^{-1})	rice-wheat rotation	3.63	3.08	3 years	(Nawaz et al., 2017)
Soil microbial biomass nitrogen (μg g^{-1})	rice-wheat rotation	628	599	3 years	(Nawaz et al., 2017)
Total carbon (g/kg)	–	16.16	12.91	27 years	(Nawaz et al., 2017)
Total nitrogen (g/kg)	–	1.06	0.97	27 years	(Nawaz et al., 2017)
Soil organic carbon (mg/L)	–	8.36	7.21	27 years	(Nawaz et al., 2017)
Soil microbial biomass carbon (μg/g)	–	152	147	27 years	(Nawaz et al., 2017)
Soil organic carbon (g kg^{-1})	–	5	2.79	2 years	Busari and Salako (2013)
Total nitrogen (g kg^{-1})	–	0.53	0.32	2 years	Busari and Salako (2013)
Soil microbial biomass carbon (μg/g)	corn-soybean and Corn-soybean-wheat-cowpea	164	105	5 years	Aziz et al. (2013)
Total nitrogen (g kg^{-1})	–	1.72	1.23	5 years	Aziz et al. (2013)
Soil organic carbon (g kg^{-1})	–	16.9	11.8	5 years	Aziz et al. (2013)
Total soil porosity (%)	–	44.7	44.6	5 years	Aziz et al. (2013)
Aggregate stability (index)	–	42.6	33.8	5 years	Aziz et al. (2013)
Soil organic carbon (g kg^{-1})	Maize-wheat	24.6	11.0	32 years	Oorts et al. (2007)
Soil Organic N (g kg^{-1})	–	2.12	1.15	32 years	Oorts et al. (2007)
Soil bulk density (Mg m^{-3})	Barley	1.42	1.24	2 years	Chatskikh and Olesen (2007)
Penetration resistance (MPa)	Barley	0.53	0.40	2 Years	Chatskikh and Olesen (2007)

NT = No tillage; PT = Plough tillage.

into the atmosphere; hence, reduces soil aggregate stability (Williams and Petticrew, 2009). Situation is even worsening in most of the developing countries, main contributor to agricultural productions, due to inadequate crop rotations, exclusion of cover crops, and poor residues management practices. Crop residues are burnt in many parts of the developing world to reduce tillage obstacles.

2.2. Bulk density and rooting depth

Agricultural management practices have direct impact on soil bulk density and rooting depth, as these practices directly alter the soil organic carbon (SOC) contents. Conventional and conservation agriculture systems may have different impacts on soil bulk density and, ultimately the rooting depth. However, soil cultivation in conventional agriculture system significantly decreases the SOC contents (Sihi et al., 2017). Initial and rapid loss of nutrients and SOC decay occurs mainly due to plant uptake of nutrients and organic matter oxidation during the conventional tillage practices (Ross, 1993).

While comparing conventional and conservation farming systems, there was significant difference in bulk density and porosity during 10-year study (Horne et al., 1992). Another long-term study of 15 years conducted in China showed an evolution in soil bulk density under different cultivations systems (Li et al., 2007). During first 6 years, there was a significant decrease in bulk density under conventional tillage, while during next 5 years there was no significant difference between both tillage systems and, interestingly and in last two years of study, the bulk density was slightly high in conventional tillage. As rooting depth is dependent on soil bulk density, therefore conservation production system decreases the root penetration and, ultimately, shallow roots develop, whereas conventional tillage promotes the root biomass and depth as well (Sidiras et al., 2001).

2.3. Nutrients dynamics

Long-term land cultivation and fertilization significantly alter soil nutrient distribution and organic matter decomposition. Non-cultivated pastures retain large amount of phosphorus (P) as organic fractions due to less decomposition of organic matter, and consequently, C and N utilization efficiency is limited due to retention of most the soil P high P conditions in pasture soils (Ye et al., 2009).

Cultivation of virgin soils causes rapid decomposition of organic matter by releasing abundant quantities of mineral N. The nature of N fractions in organic matter also dictates its release. In virgin soils, the amino acids represent about half of the total N and account for ∼60% of N decrease, while the other half of the soil organic N contributes ∼33% of the N decrease (Reinhorn and Avnimelech, 1974). The first consideration in evaluating the chemical management (which minimize N leaching and contamination of groundwater) is the estimation of N input and removal from crop (Schepers and Fox, 1989). In conservation agriculture, chemical N fertilization has low use-efficiency due to gaseous N losses (30%) into the atmosphere (Christianson et al., 2012), while N fertilizers incorporated into the soil in conventional system have less N volatilization as compared to the no till system (Shelton et al., 2017). San Francisco et al. (2011) reported that crop residues in no till system also increase the N losses through volatilization acting as barrier between soil and fertilizer. Nevertheless, these N losses can be reduced by using urease inhibitors under conservation/no tillage systems (Shelton et al., 2017).

In cultivated lands, P fertilization and organic-P mineralization increase the plant-available P in most surface soils (Brouder and Gomez-Macpherson, 2014). The P content of the subsoils are generally less affected by cultivation. The alteration in P forms due to cultivation and fertilization relates to the P content of the virgin soils and amount of P applied (Schoninger et al., 2012). As P can strongly bind to soil surfaces, conservation agriculture practices may reduce the P fixation due to less mixing to the soil. Therefore, it could be a potential threat to the environment due to more losses through runoff water because under zero tillage, P is accumulated on the soil surface (Verhulst et al., 2010). In conventional agriculture, P fixation is higher due to its contact with greater volume of soil. Deep placement of P fertilizer under dry condition is an option to avoid the P losses, nevertheless a mulch layer on soil keep the soil moist and deep placement of fertilizers is required.

Potassium (K) concentration in top soil is more when soils are less tilled, and the amount of extractable K is higher (Verhulst et al., 2010). Zero tillage or minimum tillage keeps K near to the soil surface where mostly plant roots proliferate. Furthermore, residues retention on the soil also adds K into the top-soil layers to be taken up by the plants more effectively (Govaerts et al., 2009). Although, limited information is available to illustrate the impact of no tillage on micronutrients dynamics in soil, however a significant increase in Zn and Fe concentration has been reported in soil under conservation agriculture (Kaushik et al., 2018).

2.4. Microbial biodiversity

Soil supports a variety of living organisms which contribute towards optimum functioning of agroecosystem. It has been estimated that one hectare of good quality soil may contain about 1.3 tonnes of earth worms, 1 ton of arthropods, 3 ton of bacteria and 4 ton of fungi, and many other plants and animals (Lavelle and Spain, 2001). Agricultural practices have strong impact on soil biodiversity which is especially evident in microbial biodiversity. Owing to the strong role of microbial biodiversity as biological indicator, it is the major focus of this section. In agroecosystem, soil microbes provide numerous services such as nutrient cycling, decomposition of litter, detoxification of pollutants, climate regulation and maintenance of primary production (Aislabie et al., 2013). Environmental extremes and natural variations influence microorganisms due to their close association with surroundings and fast growth rate (Allison and Martiny, 2008). Agricultural practices that affect soil organic matter cause strong impacts on microbes' activity and diversity which also depends upon soil fertility status and on soil type (Ye et al., 2009). Conventional agricultural practices for example, fallowing, intensive tillage (especially under low SOC), mono-cropping and pesticide application, are known to have negative effects on microbial populations. In contrast, general practices of conservation agriculture such as crop diversification, conservation tillage, and residue incorporation may enhance microbial activity and diversity (Campbell et al., 1997).

Crop diversification drives the activity and structure of microbial community. In contrast to the mono-cropping in conventional system, diversified crop rotation can affect microbial populations through variation in organic inputs, its types, amount and different root depths (Altieri, 1999). Legumes inclusion in crop rotation may increase nitrogen level of soil (Miglierina et al., 2000) leading to enhanced microbial activity (Ferreira et al., 2000). Microbial biomass (C and N) enhanced with long term rotations and multi-cropping systems due to the type and quality of crop residues, root density and exudation compared with continuous corn-soybean system (Moore et al., 2000). Similarly, in mixed cropping systems of oat and common vetch mixed, higher soil bacterial diversity was reported as compared with their monocultures (Qiao et al., 2012). Crop rotation can also be helpful in controlling the activity and population of pathogens (Verhulst et al., 2010). In addition, crop rotation can affect the root colonization by mycorrhizae (Castillo et al., 2006).

Conservation tillage improves microbial biomass (Guo et al., 2016), increases diversity of residue decomposers, enhances fungi to bacteria ratio, and slows the release of nutrients in surface soils (Altieri, 1999). In conservation tillage, microbial activity and diversity is usually found higher near the soil surface, however, in high till systems, microbial activity and diversity is found consistent throughout the plough layer (Alvear et al., 2005). In a study, soil microbial biomass carbon and nitrogen were 25–50% higher near soil surface (0–5 cm) with zero

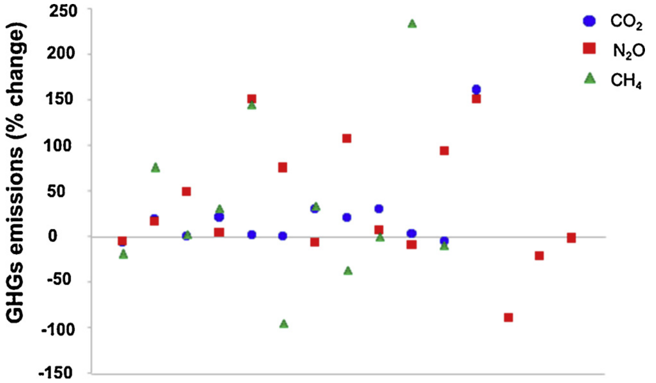

Fig. 1. Changes in greenhouse gases emissions (CO_2, N_2O and CH_4) due to conservation tillage practices as compared with conventional tillage practices. **Sources:** (Abdalla et al., 2010, 2011; Ahmad et al., 2009; Alluvione et al., 2009; Chatskikh and Olesen, 2007; Cochran et al., 1997; Curtin et al., 2000; Dendooven et al., 2012; Drury et al., 2006; Grandy et al., 2006; Guardia et al., 2016; Jantalia et al., 2008; La Scala et al., 2006; Lemke et al., 2007; Li et al., 2011; Mangalassery et al., 2014; Metay et al., 2007; Omonode et al., 2007; Oorts et al., 2007; Tellez-Rio et al., 2017; Ussiri and Lal, 2009; Volpi et al., 2018).

tillage compared to disk ploughing to a depth of 30 cm. However, in deeper layers no significant differences were found (Salinas-Garcıa et al., 2002). Additionally, no-tillage helped in higher diversity and population of *Bradyrhizobium* as compared with conventional tillage (Fierer et al. (2012).

Crop residue quality and management also have significant impact on microbial communities. Broder and Wagner (1988) studied the population of culturable bacteria and fungi in incubation bags containing decomposing residues of soybean, maize and wheat. Greater number of culturable bacteria was found in residues of soybean than in maize or wheat residues. However, the fungal populations were the highest in case of maize. The positive impacts of residue retention and reduced tillage on microbial populations are primarily because of greater carbon contents, improved soil aeration, lower fluctuations in temperature and moisture in surface soils (Verhulst et al., 2010).

Despite of positive effects of conservation tillage, it may enhance the risk of pathogens causing various diseases. Crop residues left on the soil surface under conservation tillage may serve as host for pathogens and the risk of root infection by *Pythium* and *Rhizoctonia* root rots was greater with minimum tillage with residue mulch on soil surface than residue mixing into soil (Cook, 2006). Crop rotation, which is a very fundamental practice of conservation agriculture, can be helpful to overcome this issue (Verhulst et al., 2010). Use of biocontrol inoculants along with crop rotation can also be considered to get advantages of safe and non-destructive biocontrol agents.

3. Carbon sequestration

The largest carbon stock in the terrestrial ecosystem is SOM which is double than the atmospheric C pool (Batjes, 2014) and 35% of the global land under agriculture contains approximately 12% of the soil carbon stock (Schlesinger, 1997). Any change in SOM due to soil management practices in agriculture may have a direct influence on the atmospheric GHGs concentration and ultimately the climate change. Thus, the soil management practices can be a potential tool to mitigate climate change by enhancing carbon sequestration.

The SOM stock increased when no tillage and cover crops were used (González-Sánchez et al., 2012). Likely, reduced tillage, crop rotations, and crop residue incorporation reduced CO_2 emissions from the soil (González-Sánchez et al., 2012; Govaerts et al., 2009). However, the exact mechanisms that maintain balance between decreased and increased C sequestration in the zero tillage are still not clear. So, CA practices may help in ecosystem services, including GHGs mitigation and C sequestration and impacts on soil properties to build up or enhance new SOC contents through mulching of plant residues on soil surface or as cover crops (Stagnari et al., 2009). This section contains the potential role of conventional and conservation management practices on carbon sequestration and environment quality by focusing on GHGs emissions and SOC dynamics directly affected by these management systems.

3.1. Greenhouse gases (GHGs) emissions

In previous 150 years, the atmospheric CO_2 emissions has been estimated to increase by 31% (Brovkin et al., 2004). In agricultural systems, 10–12% of total anthropogenic GHGs emissions are mainly due to agricultural practices (IPCC, 2007) which includes plant respiration, SOM decomposition and use of fossil fuel to produce agricultural inputs and to perform cultural practices for crop production (Govaerts et al., 2009). Modern cropping systems utilize substantial measures of energy sources as fossil fuels, pesticides and fertilizers. These agricultural practices, including direct and indirect sources, are causing GHGs emissions to the atmosphere (Mangalassery et al., 2014). Direct sources of GHGs emission include fossil fuel used for field operations such as tillage, irrigation, pesticide application *etc*. and GHGs emitted by microbes in cropped soils. Indirect sources include fossil energy utilized off-site to produce fertilizers and other agronomics contribution, as microbes in non-cropped sites that receive nutrients escaped from cropped fields (Gelfand et al., 2016).

One-third of the total GHGs emissions through anthropogenic activities arise from agriculture and almost 7% of total GHGs emissions come from agricultural practices (Gilbert, 2012). While soil and livestock collectively, contribute two-thirds of all GHGs emissions from agriculture (Gilbert, 2012). The fundamental source of GHGs from agriculture sources is grazing livestock and discharge of N_2O from N fertilized soils. The other potential source of GHGs emission is CH_4 discharged through ruminant livestock (especially cattle), with their digestive outgassing and their burps. However, there have been very few integrated studies on the GHGs emissions under different soil management systems. Conventional agricultural practices have 26–31% higher global warming potential as compared with conservation (zero tillage) practices (Mangalassery et al., 2014). Recent literature review also indicates that under conventional agriculture, there are more GHGs emissions compared with conservation agriculture (Fig. 1).

There are contrasting results regarding relative contribution of conventional and conservation agriculture towards N_2O emissions; some studies illustrated increased N_2O emissions in conservation agriculture systems (Abdalla et al., 2013; Ussiri et al., 2009), while others reported higher contribution of conventional agriculture compared with conservation practices, depending on the soil types as well as management practices (Almaraz et al., 2009; Wang et al., 2011). Meanwhile, some other studies reported no difference of both agricultural systems towards GHGs emissions (Bavin et al., 2009; Fuß et al., 2011).

3.2. Soil organic matter dynamics

Soil carbon consists of two major components *i.e.* organic and inorganic carbon. Agricultural management practices mainly affect SOC pool. In addition to management practices, the quality and quantity of added organic material, and microbial biodiversity also affect carbon storage in the soil. Further, type and intensity of tillage can affect the distribution of SOM in soil profile. In conservation systems with zero tillage practices, there is higher accumulation of SOM at soil surface compared with conventional system where higher SOM is found in deeper soil layers (Fig. 2). Tillage practices also influence C storage in soil by altering root development and rhizodepositions (Baker et al., 2007). In conventional tillage practices (deep ploughing), there would

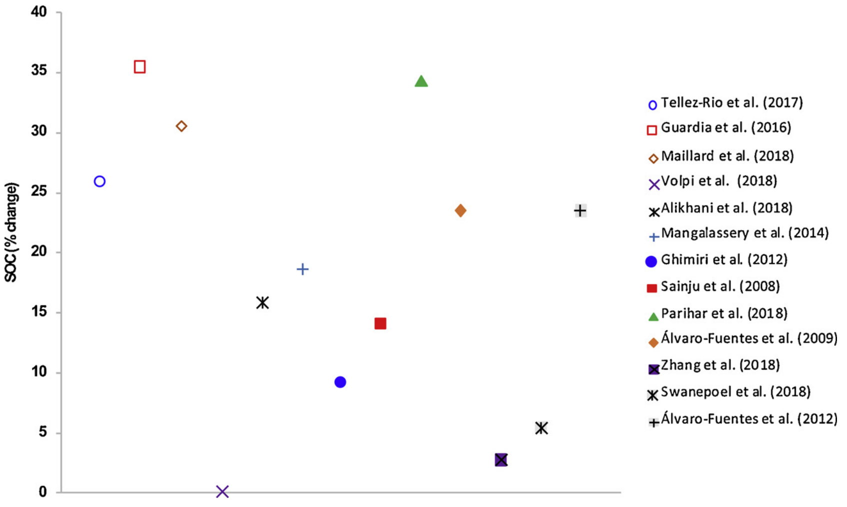

Fig. 2. Soil organic carbon changes due to conservation tillage practices as compared with conventional tillage (Alikhani et al., 2018; Álvaro-Fuentes et al., 2009, 2012; Ghimire et al., 2012; Guardia et al., 2016; Maillard et al., 2018; Mangalassery et al., 2014; Parihar et al., 2018; Sainju et al., 2008; Swanepoel et al., 2018; Tellez-Rio et al., 2017; Volpi et al., 2018).

be more root growth and penetration in soil compared with reduced or no tillage practices which can enhance root-derived C, especially in subsoil horizons. This enhanced root-derived C may help to increase the soil C stock because of its physical protection as well as chemical recalcitrance (Rasse et al., 2005). But on the other hand, intensive cultivation practices in the conventional system enhances C dynamics as physically protected SOM in soil aggregates is ultimately exposed to microbes, which is degraded, resulting in decreased C sequestration (Davidson and Janssens, 2006; Sanaullah et al., 2010).

In reduced tillage systems, SOM decomposition of residues is mainly controlled by fungal communities while in case of intensive tillage, decomposition is controlled by bacterial populations (Kladivko, 2001). Bell et al. (2006) reported that in zero tillage treatments, decomposition process in the upper soil layers (0–5 cm) was mainly because of fungal communities than bacterial communities. Land management practices resulted in an overall decline in SOC over time with the maximum loss of 557 kg C ha^{-1} yr^{-1} when crop residues were removed, and field was fertilized (Kapkiyai et al., 1999). The carbon loss was up to 49% when maize stover was kept on field and manured. It has also been reported that C is more effectively replenished by manure than maize stover (Kapkiyai et al., 1999).

4. Cropping systems

The CA principles are applicable to all types of land uses and agricultural landscapes with some regional modifications. For instance, in rice-wheat cropping system of South Asia, no tillage in wheat and direct seeding have been promoted and adapted as resource conserving and eco-friendly set of production practices (Nawaz et al., 2019). These practices help in improving soil water infiltration, crop water balance, reduce traction and labour requirements and thus improve the overall sustainability and profitability of this very much cropping system (Wall, 2007). Moreover, in rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system, conservation agricultural practices (*e.g.*, zero till wheat, direct seeded rice) help to resolve the time and edaphic conflicts existing in the conventional system (Nawaz et al., 2019). Reduced tillage and retention of crop residues changes the weeds patterns, regulate soil temperature, and suppresses the weeds growth (Nichols et al., 2015).

Cotton (*Gossypium* spp)-wheat cropping system is another important cropping system in the regional. Delay in the picking of cotton causes delay in wheat planting. However, planting wheat following conservation practices (like no tillage) may facilitate a timely planting of wheat (Buttar et al., 2012). For instance, Das et al. (2014b) recorded better seed cotton yield and wheat grain yield from permanent broadbeds for cotton, and zero tillage on the permanent beds for wheat, respectively together with residue retention. No till-planted Bt cotton performed equally good in cotton-wheat cropping system (Sihi et al., 2017). Maize (*Zea mays* L.)-wheat cropping system under no-till raised bed system was economically more profitable than the conventional tillage system, although the yield gains were comparable in both systems (Ram et al., 2012). However, in another four years field study, grain yield and water productivity of maize under no-till raised bed system were 30 and 65% higher than the conventional system (Hassan et al., 2005). Residue retention on zero tilled permanent beds further improved the water productivities of maize and wheat than the conventional tillage system (Das et al., 2018).

The water use efficiency in conservation rice (*Oryza sativa* L.)-pea (*Pisum sativum* L.) and maize-rapeseed (*Brassica napus* L.) rotation was improved by of 228 and 12%, respectively than respective conventional system. Moreover, the water productivity was 4% higher in rice-pea and maize-French bean (*Phaseolus vulgaris* L.) rotation than the single crop of rice-maize (Das et al., 2014a). Conservation agricultural practices in maize-wheat cropping system also improved the water saving by about 36% with yield improvement of 6 and 33% in wheat and maize, respectively. Residue retention in this system increased the soil organic contents and improved the system productivity (Naresh et al., 2012). CA practices have potential to improve cotton-wheat system productivity by reducing cost of production, promote early planting of crops because of improved soil fertility in addition with decreased environmental pollution.

In organic farming, particularly for the erosion-prone regions, use of CA principles has been recommended by the International Federation of Organic Agriculture Movements standards (IFOAM, 2002). Application of biochar may further improve the benefits of CA (Cornelissen et al., 2013). CA systems require quite less amount of biochar than the conventional agriculture systems (Cornelissen et al., 2013).

The modern concept of biodynamic agriculture is an integration of biological dynamics and agriculture practices (Zaller and Köpke, 2004). CA system fits well in the biodynamic agriculture as the tillage intensity and crop rotation may be changed to suit the ecology of the region and for the sustainability of agro-ecosystem.

4.1. *Crop rotations*

In the CA system, well-planned crop rotations help improving the soil health and reduce the insect- pest pressure and disease infestation (Witmer et al., 2003). A diversified crop rotation reduces the problems linked with conservation practices such as insect-pests, soil compaction and persistence of perennial weeds (Tarkalson et al., 2006) as the continuous growing of maize in no-tillage systems encourage leaf diseases, perennial weeds population, and build-up of inoculum in maize residues due to their retention (Fischer et al., 2002). The residue retention further causes problems in sowing and results in an uneven and patchy crop stand owing to allelopathic effect of stubbles (Fischer et al., 2002). Under these conditions, the problems associated with no-till maize can be reduced by killing sod in autumn season and this practice helps suppressing the insect-pests, perennial weeds and improve soil structure.

In continuous rice-wheat rotation, the practice of sesbania (*Sesbania* spp.) brown manuring (25–30 days) is very helpful in suppressing weeds and improving soil health in direct seeded aerobic rice (Nawaz et al., 2017). Moreover, inclusion of legumes in rotation improves the soil nitrogen owing to biological nitrogen fixation (Giller, 2001). For example, maize rotation with legumes improved the soil fertility (Yusuf et al., 2009), reduced the pest pressure, and improved the water use efficiency (Kureh et al., 2006). Crop rotation breaks the life cycle of several pest and diseases (*e.g.*, rust) resulting in better wheat yield (Witmer et al., 2003). Systematic and planned crop rotation minimizes the negative impacts of conventional tillage as soil compaction. At farmer's field, rotation of maize with soybean (*Glycine max* (L.) Merr.) increased the maize yield by 49% under no tillage system (Naab et al., 2017).

4.2. Weed infestation and management

Changing the tillage practices strongly influence the type, frequency and flora of weed species (Boscutti et al., 2015). The annual weeds tend to dominate in no- tillage systems while persistence of perennial weeds increase in conventional system (Table 2). For instance, Farooq and Nawaz (2014) reported dominance of narrow leaf weeds in no-tillage rice-wheat cropping system while broad leaf weeds dominated in the plough tilled system. However, the weed diversity remains higher in no-tillage system than the with plough tillage system during initial years of adoption (Sosnoskie et al., 2006). This is why that grass weeds are considered as a major threat in the adaption of CA systems in many parts of the word (Davies et al., 2002). Thus, weed management is an important aspect during initial years of CA adoption as in plough tillage, the repeated tillage helps controlling the weeds as well (Fawcett et al., 1994).

Conservation agriculture favours the prevalence of small-seeded weed species while reduction in tillage frequency does not allow the weed seeds buried in deep soil layers to come on the soil surface (Cardina et al., 1991). Weed seed buried in the soil under conventional tillage system build-ups of weeds seed in upper top 5 cm of soil (Barberi et al., 2001). The retention of crop residues, in CA, keeps the soil moist and cool, which favours the prevalence of small seeded weeds (Crutchfield et al., 1986). In CA, most of the weed seeds are left on the soil surface and are more exposed to decay and mortality (Gallandt et al., 2004). As there is no exposure of weed seeds, present in deep soil, to light and/or change in soil temperature as takes place in conventional tillage when topsoil is inverted, their germination is slowed down (Moonen and Barberi, 2004).

Although in conservation cropping system, the chemical method of weed control is the most effective; however, many factors, such as time of application, selection of herbicide and mulching of crop residues, modulate its effectiveness. The germination of weeds and herbicide bioavailability is directly impacted with residues (Khalil et al., 2018). The emergence of weed is strongly influenced by the type, nature, and quantity of residue, climatic conditions, soil type and the history of weed infestation (Chauhan et al., 2006). Moreover, the allelopathic nature of crop residues also influence the weed infestation (Farooq et al., 2011).

Crop residues also influence the efficacy and persistence of soil applied herbicides (Potter et al., 2008). In this regard, development and availability of herbicide resistant transgenic crop genotypes helped expand the CA in several regions (Duke and Powles, 2008). Nonetheless continuous use of the herbicide resistant transgenic crop genotypes in CA systems triggered the threat of herbicide- resistant weed biotypes (Farooq et al., 2011; Heap, 2014), the number of herbicide- resistant weed biotypes is increasing continuously (Heap, 2014), which demand immediate attention of researchers and policy makers. In this regard, integrated weed management offers a better option for weed management in CA systems. Herbicide rotation and use of green and brown manures in crop rotation may help control weeds in conservation agriculture (Kirkegaard et al., 2014).

5. Environmental degradation

There is growing recognition of the nature and magnitude of environmental problems associated with agricultural development. Intensification of agriculture for increased production of world food and different agricultural systems, can have serious environmental consequences due to the continuous use of irrigation, fertilizers, and pesticides (Tilman et al., 2002). This section is devoted to illustrate the potential impacts of agricultural development and different agricultural systems on various environmental resources.

5.1. Soil and water contamination

Conventional agriculture is dependent on the use of high energy inputs and agrochemicals like fertilizers and pesticides to obtain the highest possible yield. Environmental health is, however, compromised in maintaining the conventional system because agrochemicals are also considered as major polluters of environment (Tilman et al., 2002). To achieve continued increase in agricultural production to supply nutrition to increasing population, a very massive quantity of agrochemicals will be required. According to FAO, estimated global consumption of

Table 2

A summary of studies comparing weed density under conventional and conservation production systems.

Weeds	Crop	Weed density (m^{-2})		Reference
		NT	PT	
Littleseed canarygrass, sweet clover, purple nut sedge	Wheat	26	37	(Mann et al., 2004)
Littleseed canarygrass, sweet clover, toothed dock, pigweed	Wheat	17	30	(Mann et al., 2004)
Littleseed canarygrass, toothed dock	Wheat	72	71	(Khalid et al., 2009)
Littleseed canarygrass, toothed dock	Wheat	68	138	(Khaliq et al., 2013)
Littleseed canarygrass, toothed dock, pigweed	Wheat	105	177	(Farooq and Nawaz, 2014)
Littleseed canarygrass, sweet clover, toothed dock, pigweed	Wheat	87	49	(Upasani et al., 2017)
Barnyard grass, bermuda grass, chinese sprangletop, crowfoot grass	Rice	107	55	(Matloob, 2014)
Horse purslane, jungle rice, Rice flat sedge, purple nutsedge	Rice	52	137	(Matloob, 2014)
Bermuda grass, jungle rice, purple nutsedge, crackerberry, field bind weed	Cotton	45	86	(Usman et al., 2013)
Bermuda grass, barnyard grass, purple nutsedge	Maize	355	360	(Upasani et al., 2017)
Pigweed, barnyard grass, field milk thistle	Soybean	64	48	(Weber et al., 2017)

NT = No tillage; PT = Plough tillage.

fertilizer (N, P, and K) is 198 million tons in 2019 and is expected to reach 201 million tons by 2020 with an annual growth of 1.9% (FAO, 2019). It should be noted that these nutrients especially N, are highly mobile and thus, a significant amount of N and P fertilizers is lost from agricultural fields as only 30–50% and 45% of applied N and P fertilizers, respectively are taken up by plants (Cassman et al., 2002; Smil, 2000). Non-point loss of fertilizers and other agrochemicals through runoff or leaching could contribute towards contamination of ground water and eutrophication in local water resources. Eutrophication leads to serious regional economic impacts because it restricts the use of surface water and is usually considered as a consequence of conventional tillage practices combined with high input of fertilizers and heavy irrigation or rainfall (Holland, 2004). Consumption of contaminated ground water may be detrimental for public health especially in infants (Hoering and Chapman, 2004).

Due to the gravity of situation, numerous biological and physicochemical strategies have been developed to remove N and P from contaminated water (Usman et al., 2018). Environmental pollution by pesticides is another major issue associated with modern agriculture that poses serious health risks. Most of the chemicals/active ingredients used to formulate pesticides are persistent soil pollutants. According to a recent estimation, the worldwide consumption of pesticides is approximately two million tons per year (De et al., 2014). It is particularly dangerous as almost < 0.1% of the pesticides applied hit the target and remaining amount potentially contaminates the environment (air, soil and water) (Arias-Estévez et al., 2008). A major portion of applied pesticides resides in soil where their persistence and mobility is mainly governed by physiochemical properties of pesticide and soil that ultimately dictate the nature of interactions of pesticides with soil constituents (Arias-Estévez et al., 2008; Burauel and Bassmann, 2005; Usman et al., 2014). These pesticide residues can be taken up by plants, can reach surface water through runoff or can leach down to ground water constituting contamination in drinking water (Usman et al., 2014).

Runoff is the major carrier of soil particles and residual agrochemicals (soluble or bound to soil particles) to the nearby fields or water bodies with frequent damages to the ecosystem (Holland, 2004). Soil tillage can have considerable influence on runoff and leaching, water infiltration and soil erosion and conservation agriculture offer great reduction (between 15–89%) in runoff (Holland, 2004 and references cited therein). Contrary to the conventional system, very small threat to surface water contamination was recorded for no tillage system due to the dramatic decrease in runoff and quick degradation of agrochemicals by activities of soil organisms (Duiker and Myers, 2005). Transport of solutes and other chemical substances is generally reduced in conventional tillage which cut the shallow functional macropores (Jarvis, 2007). On the other hand, preferential flow of solutes is favoured in conservation tillage where formation of continuous pores is favoured (Okada et al., 2014). Contrary to the conservation tillage, however, impact of tillage practices on solute movement and other hydraulic properties varies with the kind of soil (Okada et al., 2014). No substantial difference in solute transport was observed in silty loam soils under conventional and no tillage system. However, in well-preserved structure of clayey soils under no tillage system, risk of leaching of solutes or chemical substances was higher (Okada et al., 2014).

It should, however, noted that a change in fertilizer application inputs/techniques has been recommended in many conservation tillage studies (Gaynor and Findlay, 1995). Loss of agrochemicals and nutrients in runoff could also increase due to conservation tillage driven soil compaction where they accumulate on soil surface especially if their application continues. For example, Soileau et al. (1994) reported a short phase of elevated N and P concentration in runoff after surface application of NP fertilizers in conservation tillage as compared to the conventional tillage. Similarly, conservation tillage reduced the soil loss by 49% as compared to the conventional system but increased the concentration of P (2.2 times) in runoff (Gaynor and Findlay, 1995). In addition to the direct impacts, long-term and irresponsible use of chemical fertilizers also causes buildup of toxic metals in soils which poses serious threats to the environment and food chain (Hamid et al., 2019). Chemical fertilizers are not sufficiently purified due to the economic reasons and thus, could contain various impurities and toxic metals like lead (Pb), chromium (Cr), arsenic (As), and cadmium (Cd) *etc.* (Gimeno-García et al., 1996). Under the long-term simultaneous application of fertilizers and manures, the status of toxic metals vary in soils owing to the different land use patterns as relatively higher Cd contamination was reported in greenhouse and bare vegetable field than grain crop field (Huang and Jin, 2008). On the commercial farms compared with co-operative farms the long term use of chemical fertilizers and organic manures showed greater accumulation of heavy metals in plants and soils (Parkpian et al., 2003). Similarly, long-term fertilization in greenhouse vegetable cultivation increased concentrations of Cd, Cu, and Zn by 164%, 78%, and 123%, respectively as compared to their natural background values in the same area (Liao et al., 2019). Fertilizers also indirectly contribute toward increased availability of toxic metals by decreasing the soil pH especially with atmospheric acid deposition and insufficient liming (De Vries et al., 2002).

Conservation systems are often associated with higher amount of herbicides (Fig. 3) as compared to the conventional agriculture because

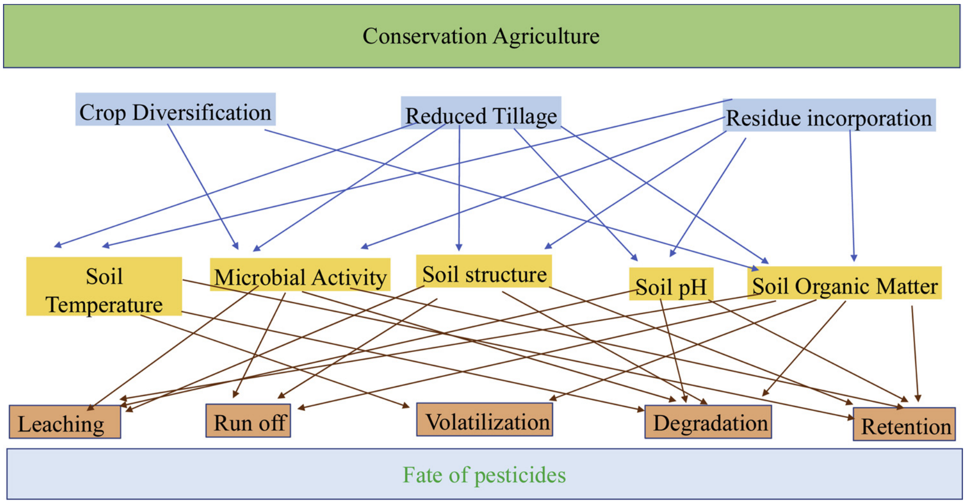

Fig. 3. Fate of pesticides under conservation agriculture. Blue boxes and arrows indicate the practices used in conservations agriculture and their possible impacts on soil properties (Pale yellow boxes), while brown boxes indicate the possible fate of pesticides due to changes in soil properties, affected by conservation agriculture.

mechanical weed control or tillage is not a valid option for the former agriculture (Alletto et al., 2010). However, it has been argued that in modern conventional agriculture, mechanical weed control has nearly disappeared and thus, relying on frequent use of herbicides for weed management (Abouziena and Haggag, 2016; Friedrich, 2005).

5.2. Fate of pesticides

Soon after application of pesticide, it may follow several routes in the agroecosystem. It may be taken up by plants, be ingested by insects, worms or microorganism following transformation in soil or adsorbed to the soil particles, run off with rain water, leach down, or may make complexes with chemicals present in soil (Chen et al., 2004). Several factors affect the fate of pesticide after its application in soil including, properties of pesticide (water solubility, volatility *etc*.), soil properties (biological, chemical and physical), weather conditions (temperature, precipitations, *etc*.) and management practices (residues, tillage, fertigation, irrigation, type of crop *etc*.) (Alletto et al., 2010). The practices of conservation agriculture affect the soil (biological, chemical and physical) properties thereby affecting the fate and natural attenuation of pesticides (Müller et al., 2007). Fig. 2 summarises main impacts of three basic practices of conservation agriculture *i.e.* crop diversification, reduced tillage and residue incorporation on bio-physicochemical properties of soil and their effect on mechanisms take part in pesticides' fate.

Accumulation of organic residues is one of most important feature of conservation agriculture, and it generally leads to enhance the interception of applied pesticide especially polar pesticides (Reddy and Locke, 1998; Zablotowicz et al., 1998). This interception differs with type, amount and distribution of organic residues in soil (Sadeghi and Isensee, 1997) and affects the applied pesticides persistence (Kah et al., 2007). The sorption capacity of organic residues is higher (10–60 times) than soil (Boyd et al., 1990), thereby may considerably alter the bioavailability and pesticide fate in soil. According to Locke et al. (2005), the presence of crop residues may increase the activity of microbes and dissipation of pesticides thereby decreasing the pesticide concentration in the surface soils. Interception of pesticide by mulch may reduce their persistence by enhancing the photo-degradation of pesticides depending upon the nature of pesticides (Selim et al., 2003). In soil, the incorporation of residues may also enhance the persistent time of pesticides due to enhanced sorption of pesticides on the residues (Mazzoncini et al., 1998). Residues may also slow down the microbial activities by decreasing air circulation and by providing physical protection to the soil surface (Turmel et al., 2015).

6. Conclusion

Conventional agriculture system is based on intensive use of agrochemicals to maximize agricultural productions; however, it is limited by associated environmental concerns and relatively lower sustainability. Conventional agricultural practices include intensive tillage, fertilization, pesticide applications, mono-cropping, and poor residue management. Conventional agricultural system leads to negative consequences such as higher GHGs emissions, deterioration of soil health, drastic impacts on system biodiversity, and environmental pollution. These issues can be avoided by using conservation agriculture which is more sustainable and less disruptive from environmental and long-term system productivity point of view. However, there are certain gaps in existing knowledge and further research should be directed at investigating: (1) specific roles of microbes in soil structural development with an emphasis on their mechanisms, (2) nutrient uptake by plants under conservation system: conservation agriculture practices sustain the soil nutrients pools within the system but the mode, transportations and transformations, especially of N and P are needed to be further investigated under no/minimum tillage conditions, (3) pesticides retention by soil and water under crop cover: the conservation agriculture especially crop cover preserves soil moisture and thus, restricts movement of water and chemicals into the atmosphere by evaporation and volatilization coupled with high infiltration rates in to the soil. Therefore, limited pesticide degradation and higher infiltration in soil can be a potential threat to the underground water. The fate of pesticides under cover crop conditions is needed to be further investigated.

Declaration of Competing Interest

We declare no conflict of interest.

References

Abdalla, M., Jones, M., Ambus, P., Williams, M., 2010. Emissions of nitrous oxide from Irish arable soils: effects of tillage and reduced N input. Nutr. Cycling Agroecosyst. 86, 53–65.

Abdalla, M., Kumar, S., Jones, M., Burke, J., Williams, M., 2011. Testing DNDC model for simulating soil respiration and assessing the effects of climate change on the CO2 gas flux from Irish agriculture. Glob. Planet. Change 78, 106–115.

Abdalla, M., Osborne, B., Lanigan, G., Forristal, D., Williams, M., Smith, P., Jones, M., 2013. Conservation tillage systems: a review of its consequences for greenhouse gas emissions. Soil Use Manage. 29, 199–209.

Abouziena, H.F., Haggag, W.M., 2016. Weed control in clean agriculture: a Review1. Planta Daninha 34, 377–392.

Ahmad, S., Li, C., Dai, G., Zhan, M., Wang, J., Pan, S., Cao, C., 2009. Greenhouse gas emission from direct seeding paddy field under different rice tillage systems in central China. Soil Tillage Res. 106, 54–61.

Aislabie, J., Deslippe, J.R., Dymond, J., 2013. Soil Microbes and Their Contribution to Soil Services. Ecosystem Services in New Zealand–conditions and Trends. Manaaki Whenua Press, Lincoln, New Zealand, pp. 143–161.

Alam, M., Islam, M., Salahin, N., Hasanuzzaman, M., 2014. Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. Transfus. Apher. Sci. 2014.

Alikhani, H.A., Karbin, S., Zadeh, B.M., 2018. Conservation Agriculture Effects on Soil Greenhouse Gas Fluxes: An Overview. https://doi.org/10.20944/preprints201804.0125.v1.

Alletto, L., Coquet, Y., Benoit, P., Heddadj, D., Barriuso, E., 2010. Tillage management effects on pesticide fate in soils. A review. Agron. Sustain. Dev. 30, 367–400.

Allison, S.D., Martiny, J.B., 2008. Resistance, resilience, and redundancy in microbial communities. Proc. Natl. Acad. Sci. 105, 11512–11519.

Alluvione, F., Halvorson, A.D., Del Grosso, S.J., 2009. Nitrogen, tillage, and crop rotation effects on carbon dioxide and methane fluxes from irrigated cropping systems. J. Environ. Qual. 38, 2023–2033.

Almaraz, J.J., Zhou, X., Mabood, F., Madramootoo, C., Rochette, P., Ma, B.-L., Smith, D.L., 2009. Greenhouse gas fluxes associated with soybean production under two tillage systems in southwestern Quebec. Soil Tillage Res. 104, 134–139.

Altieri, M.A., 1999. The ecological role of biodiversity in agroecosystems. Invertebrate Biodiversity as Bioindicators of Sustainable Landscapes. Elsevier, pp. 19–31.

Álvaro-Fuentes, J., López, M., Arrue, J., Moret, D., Paustian, K., 2009. Tillage and cropping effects on soil organic carbon in Mediterranean semiarid agroecosystems: testing the Century model. Agric. Ecosyst. Environ. 134, 211–217.

Álvaro-Fuentes, J., Morell, F.J., Plaza-Bonilla, D., Arrúe, J.L., Cantero-Martínez, C., 2012. Modelling tillage and nitrogen fertilization effects on soil organic carbon dynamics. Soil Tillage Res. 120, 32–39.

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

Arias-Estévez, M., López-Periago, E., Martínez-Carballo, E., Simal-Gándara, J., Mejuto, J.-C., García-Río, L., 2008. The mobility and degradation of pesticides in soils and the pollution of groundwater resources. Agric. Ecosyst. Environ. 123, 247–260.

Aune, J.B., 2012. Conventional, organic and conservation agriculture: production and environmental impact. In: Lichtfouse, E. (Ed.), Agroecology and Strategies for Climate Change. Springer, Netherlands, Dordrecht, pp. 149–165.

Aziz, I., Mahmood, T., Islam, K.R., 2013. Effect of long term no-till and conventional tillage practices on soil quality. Soil Tillage Res. 131, 28–35.

Baker, J.M., Ochsner, T.E., Venterea, R.T., Griffis, T.J., 2007. Tillage and soil carbon sequestration—what do we really know? Agric. Agric., Ecosyst. Environ., Appl. Soil Ecol. 118, 1–5.

Barberi, P., Bonari, E., Mazzoncini, M., 2001. Weed Density and Composition in the Winter Wheat As Influenced by Tillage Systems, Proceedings 1 World Congress on Conservation Agriculture. pp. 451–455.

Batjes, N., 2014. Total carbon and nitrogen in the soils of the world. Eur. J. Soil Sci. 65, 10–21.

Bavin, T., Griffis, T., Baker, J., Venterea, R., 2009. Impact of reduced tillage and cover cropping on the greenhouse gas budget of a maize/soybean rotation ecosystem. Agric. Ecosyst. Environ. 134, 234–242.

Bell, M., Seymour, N., Stirling, G., Stirling, A., Van Zwieten, L., et al., 2006. Impacts of management on soil biota in Vertosols supporting the broadacre grains industry in northern Australia. Arid. Soil Res. Rehabil. 44, 433–451.

Boscutti, F., Sigura, M., Gambon, N., Lagazio, C., Krusi, B.O., Bonfanti, P., 2015. Conservation tillage affects species composition but not species diversity: a comparative study in Northern Italy. Environ. Manage. 55, 443–452.

Boyd, S.A., Xiangcan, J., Lee, J.-F., 1990. Sorption of nonionic organic compounds by corn residues from a no-tillage field. J. Environ. Qual. 19, 734–738.

Broder, M., Wagner, G., 1988. Microbial colonization and decomposition of corn, wheat, and soybean residue. Soil Sci. Soc. Am. J. 52, 112–117.

Brouder, S.M., Gomez-Macpherson, H., 2014. The impact of conservation agriculture on smallholder agricultural yields: a scoping review of the evidence. Agric. Ecosyst. Environ. 187, 11–32.

Brovkin, V., Sitch, S., von Bloh, W., Claussen, M., Bauer, E., Cramer, W., 2004. Role of land cover changes for atmospheric CO2increase and climate change during the last 150 years. Glob. Chang. Biol. 10, 1253–1266.

Büks, F., Rebensburg, P., Lentzsch, P., Kaupenjohann, M., 2016. Relation of aggregate stability and microbial diversity in an incubated sandy soil. SOIL Discuss 1–29.

Burauel, P., Bassmann, F., 2005. Soils as filter and buffer for pesticides–experimental concepts to understand soil functions. Environ. Pollut. 133, 11–16.

Busari, M., Salako, F., 2013. Effect of tillage, poultry manure and NPK fertilizer on soil chemical properties and maize yield on an Alfisol at Abeokuta, south-western Nigeria. Nig. J. Soil Sci. 23, 206–218.

Buttar, G.S., Sidhu, H.S., Singh, V., Jat, M.L., Gupta, R., Singh, Y., Singh, B., 2012. Relay planting of wheat in cotton: an innovative technology for enhancing productivity and profitability of wheat in cotton–wheat production system of South Asia. Exp. Agr. 49, 19–30.

Campbell, C., Janzen, H., Juma, N., 1997. Case Studies of Soil Quality in the Canadian Prairies: Long-term Field Experiments, Developments in Soil Science. Elsevier, pp. 351–397.

Cardina, J., Regnier, E., Harrison, K., 1991. Long-term tillage effects on seed banks in three Ohio soils. Weed Sci. 39, 186–194.

Cassman, K.G., Dobermann, A., Walters, D.T., 2002. Agroecosystems, nitrogen-use efficiency, and nitrogen management. AMBIO: J. Hum. Environ. 31, 132–140.

Castillo, C.G., Rubio, R., Rouanet, J.L., Borie, F., 2006. Early effects of tillage and crop rotation on arbuscular mycorrhizal fungal propagules in an Ultisol. Biol. Fertil. Soils 43, 83–92.

Chatskikh, D., Olesen, J.E., 2007. Soil tillage enhanced CO2 and N2O emissions from loamy sand soil under spring barley. Soil Tillage Res. 97, 5–18.

Chauhan, B.S., Gill, G., Preston, C., 2006. Tillage system effects on weed ecology, herbicide activity and persistence: a review. Aust. J. Exp. Agric. 46, 1557–1570.

Chen, J.P., Pehkonen, S.O., Lau, C.-C., 2004. Phorate and Terbufos adsorption onto four tropical soils. Colloids Surf. A Physicochem. Eng. Asp. 240, 55–61.

Chou, B., O'Connor, C., Bryant, L., 2015. Climate-ready soil: how cover crops can make farms more resilient to extreme weather risks. NRDC 15, 1–3.

Christianson, L., Castellano, M., Helmers, M., Helmers, M., 2012. Nitrogen and Phosphorus Balances in Iowa Cropping Systems: Sustaining Iowa's Soil Resource. A Report to the Iowa Legislature.

Cochran, V.L., Sparrow, E.B., Schlentner, S.F., Knight, C.W., 1997. Long-term tillage and crop residue management in the subarctic: fluxes of methane and nitrous oxide. Can. J. Soil Sci. 77, 565–570.

Cook, R.J., 2006. Toward cropping systems that enhance productivity and sustainability. Proc. Natl. Acad. Sci. 103, 18389–18394.

Cornelissen, G., Martinsen, V., Shitumbanuma, V., Alling, V., Breedveld, G., et al., 2013. Biochar effect on maize yield and soil characteristics in five conservation farming sites in Zambia. Agronomy 3, 256–274.

Crutchfield, D.A., Wicks, G.A., Burnside, O.C., 1986. Effect of winter wheat (Triticum aestivum) straw mulch level on weed control. Weed Sci. 110–114.

Curtin, D., Wang, H., Selles, F., McConkey, B., Campbell, C., 2000. Tillage effects on carbon fluxes in continuous wheat and fallow–wheat rotations. Soil Sci. Soc. Am. J. 64, 2080–2086.

Das, A., Ramkrushna, G., Choudhary, B., Nagchan, S., Tripathi, A., et al., 2014a. Conservation agriculture in rice and maize based cropping system for enhancing crop and water productivity: participatory technology demonstration in North East India. Indian J. Soil Conserv. 42, 196–203.

Das, T.K., Bhattacharyya, R., Sudhishri, S., Sharma, A.R., Saharawat, Y.S., et al., 2014b. Conservation agriculture in an irrigated cotton–wheat system of the western Indo-Gangetic Plains: crop and water productivity and economic profitability. Field Crops Res. 158, 24–33.

Das, T.K., Saharawat, Y.S., Bhattacharyya, R., Sudhishri, S., Bandyopadhyay, K.K., Sharma, A.R., Jat, M.L., 2018. Conservation agriculture effects on crop and water productivity, profitability and soil organic carbon accumulation under a maize-wheat cropping system in the North-western Indo-Gangetic Plains. Field Crops Res. 215, 222–231.

Davidson, E.A., Janssens, I.A., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440, 165–173.

Davies, D., Hoad, S., Boyd, L., 2002Conference. WECOF: a new project developing enhanced weed control through improved crop and plant architecture. In: Proceedings of the UK Organic Research 2002 Conference. Organic Centre Wales, Institute of Rural Studies. University of Wales. pp. 299–302.

De, A., Bose, R., Kumar, A., Mozumdar, S., 2014. Worldwide Pesticide Use, Targeted Delivery of Pesticides Using Biodegradable Polymeric Nanoparticles. Springer, pp. 5–6.

De Vries, W., Römkens, P., Van Leeuwen, T., Bronswijk, J., 2002. 5 Heavy Metals. Agriculture, Hydrology and Water Quality. pp. 107.

Dendooven, L., Gutiérrez-Oliva, V.F., Patiño-Zúñiga, L., Ramírez-Villanueva, D.A., Verhulst, N., et al., 2012. Greenhouse gas emissions under conservation agriculture compared to traditional cultivation of maize in the central highlands of Mexico. Sci. Total Environ. 431, 237–244.

Derpsch, R., Friedrich, T., 2009. Development and current status of no-till adoption in the world. In: Proceedings on CD, 18th Triennial Conference of the International Soil Tillage Research Organisation (ISTRO). Citeseer.

Drury, C., Reynolds, W., Tan, C., Welacky, T., Calder, W., McLaughlin, N., 2006. Emissions of nitrous oxide and carbon dioxide. Soil Sci. Soc. Am. J. 70, 570–581.

Duiker, S.W., Myers, J.C., 2005. Better Soils With the No-till System: a Publication to Help Farmers Understand the Effects of No-till Systems on the Soil.

Duke, S.O., Powles, S.B., 2008. Glyphosate: a once-in-a-century herbicide. Pest Manag. Sci. 64, 319–325.

FAO, 2001. No-till Agriculture for Sustainable Land Management: Lessons: Learned From the 2000 Brazil Study Tour. Draft for TCI Occasional Paper Series. FAO Investment Centre Division, Rome.

FAO, 2018. Conservation Agriculture. http://www.fao.org/ag/ca/1a.html.

FAO, 2019. World Fertilizer Trends and Outlook to 2020. http://www.fao.org/3/a-i6895e.pdf.

Farooq, M., Jabran, K., Cheema, Z.A., Wahid, A., Siddique, K.H., 2011. The role of allelopathy in agricultural pest management. Pest Manag. Sci. 67, 493–506.

Farooq, M., Nawaz, A., 2014. Weed dynamics and productivity of wheat in conventional and conservation rice-based cropping systems. Soil Tillage Res. 141, 1–9.

Fawcett, R.S., Christensen, B.R., Tierney, D.P., 1994. The impact of conservation tillage on pesticide runoff into surface water: a review and analysis. J. Soil Water Conserv. 49, 126–135.

Ferreira, M.C., Andrade, Dd.S., Chueire, L.Md.O., Takemura, S.M., Hungria, M., 2000. Tillage method and crop rotation effects on the population sizes and diversity of bradyrhizobia nodulating soybean. Soil Biol. Biochem. 32, 627–637.

Fierer, N., Lauber, C.L., Ramirez, K.S., Zaneveld, J., Bradford, M.A., Knight, R., 2012. Comparative metagenomic, phylogenetic and physiological analyses of soil microbial communities across nitrogen gradients. ISME J. 6, 1007–1017.

Fischer, R., Santiveri, F., Vidal, I., 2002. Crop rotation, tillage and crop residue management for wheat and maize in the sub-humid tropical highlands: I. Wheat and legume performance. Field Crops Res. 79, 107–122.

Friedrich, T., 2005. Does No-Till Farming Require More Herbicides? Outlooks Pest Manag. 16, 188–191.

Friedrich, T., Derpsch, R., Kassam, A., 2012. Overview of the global spread of conservation agriculture. Field Actions Sci. Rep. 6, 1–7.

Fuß, R., Ruth, B., Schilling, R., Scherb, H., Munch, J.C., 2011. Pulse emissions of N2O and CO2 from an arable field depending on fertilization and tillage practice. Agric. Ecosyst. Environ. 144, 61–68.

Gallandt, E.R., Fuerst, E.P., Kennedy, A.C., 2004. Effect of tillage, fungicide seed treatment, and soil fumigation on seed bank dynamics of wild oat (Avena fatua). Weed Sci. 52, 597–604.

Gaynor, J., Findlay, W., 1995. Soil and phosphorus loss from conservation and conventional tillage in corn production. J. Environ. Qual. 24, 734–741.

Gelfand, I., Shcherbak, I., Millar, N., Kravchenko, A.N., Robertson, G.P., 2016. Long-term nitrous oxide fluxes in annual and perennial agricultural and unmanaged ecosystems in the upper Midwest USA. Glob. Chang. Biol. 22, 3594–3607.

Ghimire, R., Adhikari, K.R., Chen, Z.-S., Shah, S.C., Dahal, K.R., 2012. Soil organic carbon sequestration as affected by tillage, crop residue, and nitrogen application in rice–wheat rotation system. Paddy Water Environ. 10, 95–102.

Gilbert, N., 2012. One-third of our greenhouse gas emissions come from agriculture. Nature News 31.

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. CAB International, Wallingford, UK, pp. 423.

Gimeno-García, E., Andreu, V., Boluda, R., 1996. Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. Environ. Pollut. 92, 19–25.

González-Sánchez, E.J., Ordóñez-Fernández, R., Carbonell-Bojollo, R., Veroz-González, O., Gil-Ribes, J.A., 2012. Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. Soil Tillage Res. 122, 52–60.

Govaerts, B., Verhulst⁎, N., Castellanos-Navarrete, A., Sayre, K.D., Dixon, J., Dendooven, L., 2009. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. Crit. Rev. Plant Sci. 28, 97–122.

Grandy, A.S., Loecke, T.D., Parr, S., Robertson, G.P., 2006. Long-term trends in nitrous oxide emissions, soil nitrogen, and crop yields of till and no-till cropping systems. J. Environ. Qual. 35, 1487–1495.

Guardia, G., Tellez-Rio, A., García-Marco, S., Martin-Lammerding, D., Tenorio, J.L., Ibáñez, M.Á., Vallejo, A., 2016. Effect of tillage and crop (cereal versus legume) on greenhouse gas emissions and Global Warming Potential in a non-irrigated Mediterranean field. Agric. Ecosyst. Environ. 221, 187–197.

Guo, L.J., Lin, S., Liu, T.Q., Cao, C.G., Li, C.F., 2016. Effects of conservation tillage on topsoil microbial metabolic characteristics and organic carbon within aggregates under a rice (Oryza sativa L.)-Wheat (Triticum aestivum L.) cropping system in Central China. PLoS One 11, e0146145.

Hamid, Y., Tang, L., Sohail, M.I., Cao, X., Hussain, B., et al., 2019. An explanation of soil amendments to reduce cadmium phytoavailability and transfer to food chain. Sci. Total Environ. 660, 80–96.

Hassan, I., Hussain, Z., Akbar, G., et al., 2005. Effect of permanent raised beds on water productivity for irrigated maize–wheat cropping system. In: Evaluation and Performance of Permanent Raised Bed Cropping Systems in Asia, Australia and Mexico. In: In: Roth, C.H. (Ed.), ACIAR Proceedings 121. ACIAR, Griffith, Australia, pp. 59–65.

Heap, I., 2014. Herbicide Resistant Weeds, Integrated Pest Management. Springer, pp. 281–301.

Hoering, H., Chapman, D., 2004. Nitrate and Nitrite in Drinking Water. WHO Drinking Water Series. IWA Publishing., London.

Holland, J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agric. Ecosyst. Environ. 103, 1–25.

Horne, D., Ross, C., Hughes, K., 1992. Ten years of a maize/oats rotation under three tillage systems on a silt loam in New Zealand. 1. A comparison of some soil properties. Soil Tillage Res. 22, 131–143.

Horwath, W., 2008. Tillage and Crop Management Effects on Air, Water, and Soil Quality in California. UCANR Publications.

Huang, S.W., Jin, J.Y., 2008. Status of heavy metals in agricultural soils as affected by different patterns of land use. Environ. Monit. Assess. 139, 317–327.

IFOAM, I., 2002. IFOAM Basic Standards for Organic Production and Processing. International Federation of Organic Agricultural Movements (IFOAM) Bonn.

IPCC, 2007. Climate Change 2007-Mitigation of Climate Change: Working Group III Contribution to the Fourth Assessment Report of the IPCC. Cambridge University Press.

Jantalia, C.P., dos Santos, H.P., Urquiaga, S., Boddey, R.M., Alves, B.J., 2008. Fluxes of nitrous oxide from soil under different crop rotations and tillage systems in the South of Brazil. Nutr. Cycling Agroecosyst. 82, 161–173.

Jarvis, N., 2007. A review of non-equilibrium water flow and solute transport in soil macropores: principles, controlling factors and consequences for water quality. Eur. J. Soil Sci. 58, 523–546.

Kah, M., Beulke, S., Brown, C.D., 2007. Factors influencing degradation of pesticides in soil. J. Agric. Food Chem. 55, 4487–4492.

Kapkiyai, J.J., Karanja, N.K., Qureshi, J.N., Smithson, P.C., Woomer, P.L., 1999. Soil organic matter and nutrient dynamics in a Kenyan nitisol under long-term fertilizer and organic input management. Soil Biol. Biochem. 31, 1773–1782.

Kaushik, U., Raj, D., Rani, P., Antil, R., 2018. Impact of zero tillage on available nutrients status on pearlmillet wheat cropping system. Int. J. Chem. Stud. 6, 2997–3000.

Khalid, U., Khalil, S.K., Fida, M., Khan, M.A., Khan, A.Z., 2009. Weed management in wheat as affected by tillage and herbicides. Pak. J. Weed Sci. Res. 15, 155–169.

Khalil, Y., Siddique, K.H., Ward, P., Piggin, C., Bong, S.H., et al., 2018. A bioassay for prosulfocarb, pyroxasulfone and trifluralin detection and quantification in soil and crop residues. Crop Pasture Sci. 69, 606–616.

Khaliq, A., Shakeel, M., Matloob, A., Hussain, S., Tanveer, A., Murtaza, G., 2013. Influence of tillage and weed control practices on growth and yield of wheat. Phil. J. Crop Sci. 38 00-00.

Kirkegaard, J.A., Conyers, M.K., Hunt, J.R., Kirkby, C.A., Watt, M., Rebetzke, G.J., 2014. Sense and nonsense in conservation agriculture: principles, pragmatism and productivity in Australian mixed farming systems. Agric. Ecosyst. Environ. 187, 133–145.

Kladivko, E.J., 2001. Tillage systems and soil ecology. Soil Tillage Res. 61, 61–76.

Kureh, I., Kamara, A., Tarfa, B., 2006. Influence of cereal-legume rotation on Striga control and maize grain yield in farmers' fields in the Northern Guinea savanna of Nigeria. J. Agric. Rural Devel. Trop. Subtrop. 107, 41–54.

La Scala, N., Bolonhezi, D., Pereira, G.T., 2006. Short-term soil CO2 emission after conventional and reduced tillage of a no-till sugar cane area in southern Brazil. Soil Tillage Res. 91, 244–248.

Lal, R., 2008. Carbon sequestration. Philos. Trans. Biol. Sci. 363, 815–830.

Lavelle, P., Spain, A., 2001. Soil Ecology Kluwer Scientific Publications. Amsterdam.

Le Quéré, C., Moriarty, R., Andrew, R.M., Canadell, J.G., Sitch, S., et al., 2015. Global carbon budget 2015. Earth Syst. Sci. Data Discuss. 7, 349–396.

Lemke, P., Ren, J., Alley, R.B., Allison, I., Carrasco, J., et al., 2007. Observations: Changes in Snow, Ice and Frozen Ground.

Li, D., Liu, M., Cheng, Y., Wang, D., Qin, J., et al., 2011. Methane emissions from double-rice cropping system under conventional and no tillage in southeast China. Soil Tillage Res. 113, 77–81.

Li, H., Gao, H., Wu, H., Li, W., Wang, X., He, J., 2007. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. Arid. Soil Res. Rehabil. 45, 344–350.

Liao, Z., Chen, Y., Ma, J., Islam, M., Weng, L., Li, Y., 2019. Cd, Cu, and Zn accumulations caused by long-term fertilization in greenhouse soils and their potential risk assessment. Int. J. Environ. Res. Public Health 16, 2805.

Locke, M.A., Zablotowicz, R.M., Bauer, P.J., Steinriede, R.W., Gaston, L.A., 2005. Conservation cotton production in the southern United States: herbicide dissipation in soil and cover crops. Weed Sci. 53, 717–727.

Maillard, É., McConkey, B.G., St. Luce, M., Angers, D.A., Fan, J., 2018. Crop rotation, tillage system, and precipitation regime effects on soil carbon stocks over 1 to 30 years in Saskatchewan. Canada. Soil and Tillage Res. 177, 97–104.

Mangalassery, S., Sjögersten, S., Sparkes, D.L., Sturrock, C.J., Craigon, J., Mooney, S.J., 2014. To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils? Sci. Rep. 4, 4586.

Mann, R.A., Ashraf, M., Hassan, G., 2004. Wheat establishment with zero tillage for integrated weed management. Pak. J. Weed Sci. Res 10, 17–24.

Matloob, A., 2014. Weed Dynamics and Management Studies in Direct Seeded Rice (Oryza Sativa L.). PhD dissertation. Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Mazzoncini, M., Lorenzi, R., Risaliti, R., Sorce, C., Ginanni, M., Curadi, M., Pini, R., 1998. Diclofop-methyl dissipation in clay soil under different tillage systems in central Italy. Soil Tillage Res. 46, 241–250.

Metay, A., Oliver, R., Scopel, E., Douzet, J.-M., Moreira, J.A.A., et al., 2007. N2O and CH4 emissions from soils under conventional and no-till management practices in Goiânia (Cerrados, Brazil). Geoderma 141, 78–88.

Miglierina, A., Iglesias, J., Landriscini, M., Galantini, J., Rosell, R., 2000. The effects of crop rotation and fertilization on wheat productivity in the Pampean semiarid region of Argentina. 1. Soil physical and chemical properties. Soil Tillage Res. 53, 129–135.

Moonen, A., Barberi, P., 2004. Size and composition of the weed seedbank after 7 years of different cover-crop-maize management systems. Weed Res. 44, 163–177.

Moore, J., Klose, S., Tabatabai, M., 2000. Soil microbial biomass carbon and nitrogen as affected by cropping systems. Biol. Fertil. Soils 31, 200–210.

Müller, K., Magesan, G., Bolan, N., 2007. A critical review of the influence of effluent irrigation on the fate of pesticides in soil. Agric. Ecosyst. Environ. 120, 93–116.

Musinguzi, P., Ebanyat, P., Tenywa, J.S., Basamba, T.A., Tenywa, M.M., Mubiru, D., 2015. Precision of farmer-based fertility ratings and soil organic carbon for crop production on a Ferralsol. Solid Earth 6, 1063–1073.

Mwango, S.B., Msanya, B.M., Mtakwa, P.W., Kimaro, D.N., Deckers, J., Poesen, J., 2016. Effectiveness OF mulching UnderMirabain controlling soil Erosion, fertility restoration and crop yield in the Usambara Mountains. Tanzania. Land Degrad. Develop. 27, 1266–1275.

Naab, J.B., Mahama, G.Y., Yahaya, I., Prasad, P.V.V., 2017. Conservation agriculture improves soil quality, crop yield, and incomes of smallholder farmers in North Western Ghana. Front. Plant Sci. 8, 996.

Naresh, R., Singh, S., Chauhan, P., 2012. Influence of conservation agriculture, permanent raised bed planting and residue management on soil quality and productivity in maize–wheat system in western Uttar Pradesh. Int. J. Life Sci. Biotech. Pharm. Res. 1, 27–34.

Nawaz, A., Farooq, M., Nadeem, F., Siddique, K.H., Lal, R., 2019. Rice–wheat cropping systems in South Asia: issues, options and opportunities. Crop Pasture Sci. 70, 395–427.

Nawaz, A., Lal, R., Shrestha, R.K., Farooq, M., 2017. Mulching affects soil properties and greenhouse gas emissions under long-term No-Till and plough-till systems in Alfisol of Central Ohio. Land Degrad. Dev. 28, 673–681.

Nichols, V., Verhulst, N., Cox, R., Govaerts, B., 2015. Weed dynamics and conservation agriculture principles: a review. Field Crops Res. 183, 56–68.

Okada, E., Costa, J.L., Bedmar, F., Barbagelata, P., Irizar, A., Rampoldi, E.A., 2014. Effect of conventional and no-till practices on solute transport in long term field trials. Soil Tillage Res. 142, 8–14.

Omonode, R.A., Vyn, T.J., Smith, D.R., Hegymegi, P., Gál, A., 2007. Soil carbon dioxide and methane fluxes from long-term tillage systems in continuous corn and corn–-soybean rotations. Soil Tillage Res. 95, 182–195.

Oorts, K., Merckx, R., Gréhan, E., Labreuche, J., Nicolardot, B., 2007. Determinants of annual fluxes of CO2 and N2O in long-term no-tillage and conventional tillage systems in northern France. Soil Tillage Res. 95, 133–148.

Ozturk, S., Aslim, B., 2010. Modification of exopolysaccharide composition and production by three cyanobacterial isolates under salt stress. Environ. Sci. Pollut. Res. - Int. 17, 595–602.

Pajares, S., Bohannan, B.J.M., 2016. Ecology of nitrogen fixing, nitrifying, and denitrifying microorganisms in tropical forest soils. Front. Microbiol. 7.

Parihar, C., Jat, S., Singh, A., Datta, A., Parihar, M., et al., 2018. Changes in carbon pools and biological activities of a sandy loam soil under medium-term conservation agriculture and diversified cropping systems. Eur. J. Soil Sci. 69, 902–912.

Parkpian, P., Leong, S.T., Laortanakul, P., Thunthaisong, N., 2003. Regional monitoring of lead and cadmium contamination in a tropical grazing land site. Thailand. Environ. Monit. Assess. 85, 157–173.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R., 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience 55, 573–582.

Potter, T.L., Truman, C.C., Strickland, T.C., Bosch, D.D., Webster, T.M., 2008. Herbicide incorporation by irrigation and tillage impact on runoff loss. J. Environ. Qual. 37, 839–847.

Qiao, Y., Li, Z., Wang, X., Zhu, B., Hu, Y., Zeng, Z., 2012. Effect of legume-cereal mixtures on the diversity of bacterial communities in the rhizosphere. Plant Soil Environ. 58, 174–180.

Quesada, C., Lloyd, J., Schwarz, M., Patino, S., Baker, T., et al., 2010. Variations in chemical and physical properties of Amazon forest soils in relation to their genesis. Biogeosciences 7, 1515–1541.

Rasse, D.P., Rumpel, C., Dignac, M.-F., 2005. Is soil carbon mostly root carbon? Mechanisms for a specific stabilisation. Plant Soil 269, 341–356.

Reddy, K.N., Locke, M.A., 1998. Sulfentrazone sorption, desorption, and mineralization in soils from two tillage systems. Weed Sci. 494–500.

Reinhorn, T., Avnimelech, Y., 1974. Nitrogen release associated with the decrease in soil organic matter in newly cultivated soils 1. J. Environ. Qual. 3, 118–121.

Ross, S.M., 1993. Organic matter in tropical soils: current conditions, concerns and prospects for conservation. Prog. Phys. Geogr. 17, 265–305.

Sadeghi, A., Isensee, A., 1997. Alachlor and cyanazine persistence in soil under different tillage and rainfall regimes. Soil Sci. 162, 430–438.

Sainju, U.M., Senwo, Z.N., Nyakatawa, E.Z., Tazisong, I.A., Reddy, K.C., 2008. Soil carbon and nitrogen sequestration as affected by long-term tillage, cropping systems, and nitrogen fertilizer sources. Agric. Ecosyst. Environ. 127, 234–240.

Salinas-Garcıa, J., de Velázquez-García, J., Gallardo-Valdez, M., Dıaz-Mederos, P., Caballero-Hernández, F., Tapia-Vargas, L., Rosales-Robles, E., 2002. Tillage effects on microbial biomass and nutrient distribution in soils under rain-fed corn production in central-western Mexico. Soil Tillage Res. 66, 143–152.

San Francisco, S., Urrutia, O., Martin, V., Peristeropoulos, A., Garcia-Mina, J.M., 2011. Efficiency of urease and nitrification inhibitors in reducing ammonia volatilization from diverse nitrogen fertilizers applied to different soil types and wheat straw mulching. J. Sci. Food Agric. 91, 1569–1575.

Sanaullah, M., Chabbi, A., Leifeld, J., Bardoux, G., Billou, D., Rumpel, C., 2010. Decomposition and stabilization of root litter in top- and subsoil horizons: what is the difference? Plant Soil 338, 127–141.

Saturnino, H.M., Landers, J.N., 1997. O meio ambiente e o plantio direto. Brasília: Embrapa-SPI 97.

Schepers, J.S., Fox, R., 1989. Estimation of N Budgets for Crops, Developments in Agricultural and Managed Forest Ecology. Elsevier, pp. 221–246.

Schlesinger, W., 1997. Biogeochemistry: An Analysis of Global Change. CA: Academic, San Diego.

Schoninger, E.L., Gatiboni, L.C., Ernani, P.R., 2012. Rhizosphere pH and phosphorus forms in an Oxisol cultivated with soybean, brachiaria grass, millet and sorghum. Sci.

Agric. 69, 259–264.

Selim, H., Zhou, L., Zhu, H., 2003. Herbicide retention in soil as affected by sugarcane mulch residue. J. Environ. Qual. 32, 1445–1454.

Seufert, V., Ramankutty, N., Foley, J.A., 2012. Comparing the yields of organic and conventional agriculture. Nature 485, 229.

Shelton, R.E., Jacobsen, K.L., McCulley, R.L., 2017. Cover crops and fertilization alter nitrogen loss in organic and conventional conservation agriculture systems. Front. Plant Sci. 8, 2260.

Shu, X., Zhu, A.-n., Zhang, J.-b., Yang, W.-l., Xin, X.-l., Zhang, X.-f., 2015. Changes in soil organic carbon and aggregate stability after conversion to conservation tillage for seven years in the Huang-Huai-Hai Plain of China. J. Integr. Agric. 14, 1202–1211.

Sidiras, N., Bilalis, D., Vavoulidou, E., 2001. Effects of tillage and fertilization on some selected physical properties of soil (0–30 cm depth) and on the root growth dynamic of winter barley (Hordeum vulgare cv. Niki). J. Agron. Crop. Sci. 187, 167–176.

Sihi, D., Dari, B., Sharma, D.K., Pathak, H., Nain, L., Sharma, O.P., 2017. Evaluation of soil health in organic vs conventional farming of basmati rice in North India. J. Soil Sci. Plant Nutr. 180, 389–406.

Singh, B.P., Cowie, A.L., Chan, K.Y., 2011. Soil Health and Climate Change. Springer Science & Business Media.

Smil, V., 2000. Phosphorus in the environment: natural flows and human interferences. Ann. Rev. Energ. Environ. 25, 53–88.

Soileau, J., Touchton, J., Hajek, B., Yoo, K., 1994. Sediment, nitrogen, and phosphorus runoff with conventional-and conservation-tillage cotton in a small watershed. J. Soil Water Conserv. 49, 82–89.

Sosnoskie, L.M., Herms, C.P., Cardina, J., 2006. Weed seedbank community composition in a 35-yr-old tillage and rotation experiment. Weed Sci. 54, 263–273.

Stagnari, F., Ramazzotti, S., Pisante, M., 2009. Conservation Agriculture: a Different Approach for Crop Production Through Sustainable Soil and Water Management: a Review, Organic Farming, Pest Control and Remediation of Soil Pollutants. Springer, pp. 55–83.

Swanepoel, C.M., Rötter, R.P., Van der Laan, M., Annandale, J.G., Beukes, D.J., et al., 2018. The benefits of conservation agriculture on soil organic carbon and yield in southern Africa are site-specific. Soil Tillage Res. 183, 72–82.

Tarkalson, D.D., Hergert, G.W., Cassman, K.G., 2006. Long-term effects of tillage on soil chemical properties and grain yields of a dryland winter wheat–sorghum/corn–fallow rotation in the Great Plains. Agron. J. 98, 26–33.

Tellez-Rio, A., Vallejo, A., García-Marco, S., Martin-Lammerding, D., Tenorio, J.L., Rees, R.M., Guardia, G., 2017. Conservation Agriculture practices reduce the global warming potential of rainfed low N input semi-arid agriculture. Eur. J. Agron. 84, 95–104.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418, 671.

Turmel, M.-S., Speratti, A., Baudron, F., Verhulst, N., Govaerts, B., 2015. Crop residue management and soil health: a systems analysis. Agric. Syst. 134, 6–16.

Upasani, R., Barla, S., Puran, A., 2017. Effect of tillage and weed control methods in maize (Zea mays)-Wheat (Triticum aestivum) cropping system. Int. J. Bio-resource Stress. Manag. 8, 758–766.

Usman, K., Khan, N., Khan, M.U., ur Rehman, A., Ghulam, S., 2013. Impact of tillage and herbicides on weed density, yield and quality of cotton in wheat based cropping system. J. Integr. Agric. 12, 1568–1579.

Usman, M., Byrne, J.M., Chaudhary, A., Orsetti, S., Hanna, K., et al., 2018. Magnetite and green rust: synthesis, properties, and environmental applications of mixed-valent Iron minerals. Chem. Rev. 118, 3251–3304.

Usman, M., Tascone, O., Faure, P., Hanna, K., 2014. Chemical oxidation of hexachlorocyclohexanes (HCHs) in contaminated soils. Sci. Total Environ. 476–477, 434–439.

Ussiri, D.A., Lal, R., 2009. Long-term tillage effects on soil carbon storage and carbon dioxide emissions in continuous corn cropping system from an alfisol in Ohio. Soil Tillage Res. 104, 39–47.

Ussiri, D.A., Lal, R., Jarecki, M.K., 2009. Nitrous oxide and methane emissions from long-term tillage under a continuous corn cropping system in Ohio. Soil Tillage Res. 104, 247–255.

Verhulst, N., Govaerts, B., Verachtert, E., Castellanos-Navarrete, A., Mezzalama, M., et al., 2010. Conservation agriculture, improving soil quality for sustainable production systems. Adv. Soil Sci.: Food Secur. Soil Qual. 137–208.

Volpi, I., Antichi, D., Ambus, P.L., Bonari, E., Di, Nassio, Nasso, N., Bosco, S., 2018. Minimum tillage mitigated soil N2O emissions and maximized crop yield in faba bean in a Mediterranean environment. Soil Tillage Res. 178, 11–21.

Wall, P.C., 2007. Tailoring conservation agriculture to the needs of small farmers in developing countries. J. Crop Improv. 19, 137–155.

Walters, J.P., Archer, D.W., Sassenrath, G.F., Hendrickson, J.R., Hanson, J.D., et al., 2016. Exploring agricultural production systems and their fundamental components with system dynamics modelling. Ecol. Modell. 333, 51–65.

Wang, W., Dalal, R.C., Reeves, S.H., BUTTERBACH-BAHL, K., Kiese, R., 2011. Greenhouse gas fluxes from an Australian subtropical cropland under long-term contrasting management regimes. Glob. Chang. Biol. 17, 3089–3101.

Weber, J., Kunz, C., Peteinatos, G., Zikeli, S., Gerhards, R., 2017. Weed control using conventional tillage, reduced tillage, no-tillage, and cover crops in organic soybean. Agriculture 7, 43.

Williams, N., Petticrew, E., 2009. Aggregate stability in organically and conventionally farmed soils. Soil use Manage. 25, 284–292.

Witmer, J., Hough-Goldstein, J., Pesek, J., 2003. Ground-dwelling and foliar arthropods in four cropping systems. Environ. Entomol. 32, 366–376.

Ye, R., Wright, A.L., Inglett, K., Wang, Y., Ogram, A.V., Reddy, K., 2009. Land-use effects on soil nutrient cycling and microbial community dynamics in the Everglades Agricultural Area. Florida. Commun. Soil Sci. Plant Anal. 40, 2725–2742.

Yusuf, A., Iwuafor, E.N., Abaidoo, R., Olufajo, O., Sanginga, N., 2009. Grain legume rotation benefits to maize in the northern Guinea savanna of Nigeria: fixed-nitrogen versus other rotation effects. Nutr. Cycl. Agroecosystems 84, 129–139.

Zablotowicz, R.M., Locke, M.A., Smeda, R.L., 1998. Degradation of 2, 4-D and fluometuron in cover crop residues. Chemosphere 37, 87–101.

Zaller, J.G., Köpke, U., 2004. Effects of traditional and biodynamic farmyard manure amendment on yields, soil chemical, biochemical and biological properties in a long-term field experiment. Biol. Fertil. Soils 40, 222–229.