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A Review on: Effect of Tillage and Crop Residue on Soil Carbon and Carbon Dioxide Emission

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Abstract
Agricultural soils can act as sources and sinks for CO_2 and other greenhouse gases. Whether soils act as a sink or source depends upon the management of the soil. The fluxes of CO_2 between the atmosphere and the soil are an important link in the C cycle, and the processes affect the atmospheric concentration of CO_2. Therefore, objective of this paper is to review the effect of tillage and crop residue on soil carbon and carbon dioxide emission. Tillage induces the loss of C as CO_2 by breaking up soil aggregates and exposing the protected organic matter to microbes, minimizing soil disturbance decreases SOC decomposition rate, then this change in management practice would cause decreased transfer of C from soil to the atmosphere. Conservation tillage combined with crop residues on the soil surface has been identified as an important for sequestering carbon from the atmosphere. Crop residue management is another important method of sequestering C in soil and increasing the soil OM content and giving protection against erosion. Surface applied crop residues decompose more slowly than those that are incorporated by tillage, because they have less contact with soil microorganisms and soil water. Clay particles tend to remain in a flocculated state reducing the exposure and mineralization of organic carbon adsorbed on clay particle surfaces. Carbon inventories are higher in the soils, which have higher clay content and higher fractions of clay associated with high organic matter, changes in organic matter properties that correlate with soil texture. The greatest reductions in CO_2 emission are associated with those tillage systems having less soil disturbance. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored.

1. Introduction

Carbon dioxide is constantly being exchanged among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, plants, and animals. However, emissions and removal of CO_2 by these natural processes tend to balance (NRC, 2010). Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere, Soil carbon-dioxide emissions comprise an important component of the global carbon cycle and represent the largest terrestrial source of CO_2 to the atmosphere and now it reaches the 370 ppm (Schlesinger *et al*., 2000). The increase of the atmospheric CO_2 concentration contributes to global climate change because of the growth of greenhouse gas effect. Nowadays Agricultural lead to the emission of several greenhouse gases (CO_2, CH_4 and N_2O), that differ with regards on their ability to absorb the long wave radiation, and depending on their specific radiation forcing and residence time in the atmosphere.

Hence, agriculture contributes about 1% of CO_2 emissions, about 40% of CH_4 and 60% of N_2O for the increment of GHG annually (Watson *et al*., 1996; Tóth, 2011). Although CO_2 emission of agriculture originates primarily from deforestation and fossil fuel consumption of agricultural machinery, the amount of CO_2 getting into the air from agricultural practices is not neglected, it was estimated that 20% of CO_2 in the atmosphere come from agricultural production (Bouwman, 1990; Lokupitiya *et al*., 2006; Stafford, 2007). Soils can function either as a source or a sink for atmospheric greenhouse gas effect depending on land use and soil management. Appropriate management can enable agricultural soils to be a net sink for sequestering atmospheric CO_2 and other greenhouse gas effect (GHG) (West *et al*., 2002). The CO_2 emission from soil to the atmosphere, a primary mechanism of C loss from soils, is attributed to the metabolism of plant roots, micro flora and fauna (Rastogi *et al*., 2002). Rates of soil respiration are controlled by several factors including soil temperature, quantity and quality of soil organic matter (SOM), soil moisture, the CO_2 concentration gradient between the soil and the atmosphere, pore size distribution and wind speed (Raich et al., 2000; Jarecki *et al*., 2006). In addition, CO_2 emissions are influenced by practices such as tillage and residue management (Osozawa *et al*., 1995).

The fluxes of CO_2 between the atmosphere and the soil are an important link in the C cycle, and the processes that mediate these fluxes affect the atmospheric concentration of carbon-dioxide (CO_2). Application of good agricultural practices and adequate soil tillage methods has not only favorable effect on soil physical properties but it could also reduce soil respiration. So soil organic matter content can be preserved and amount of CO_2 getting into the air can be reduced. The emission of greenhouse gases from the soils is not understandable for all scholars and farmers. But agricultural practice playing an important role in the emission of green house gases, these gases may diffuse directly from the soil or indirectly in the atmosphere through subsurface drainage after leaching (Sawamoto *et al*., 2003; Le Mer *et al*., 2001). Different ideologies are promoting concerning the effect of tillage, crop residue and soil texture on the soil carbon and carbon dioxide emission regardless of soil and weather condition. Therefore, the objective of this paper is to review soil carbon and CO_2 emission influenced by tillage, crop residue and soil texture.

2. Literature review

2.1. Dynamics of organic carbon in soils

The stock of organic carbon present in natural soils represents a dynamic balance between the input of dead plant material and loss from decomposition (mineralization). Soil organic matter (SOM) has a very complex and heterogeneous composition and it is generally mixed or associated with the mineral soil constituents (William, 1999). The different C pools existing in the soil have different mean residence times, ranging from one year to a few years depending on the biochemical composition (Puget *et al*., 1995; Balesdent *et al*., 2000). Carbon dioxide (CO_2) is much more abundant in soil gas (the air in soil) than in the atmosphere. That is because plant roots respire and produce CO_2, and because oxidative decay of organic matter produces CO_2. As a result, concentrations of CO_2 in soil gas are greater than the atmospheric concentration. It is therefore important to understand the dynamics of soil carbon as well as its role in terrestrial ecosystem carbon balance and the global carbon cycle. The loss of soil organic carbon by conversion of natural vegetation to cultivated use is well known. Various land-uses result in very rapid declines in soil organic matter (FAO, 2001). Much of this loss in soil organic carbon can be attributed to reduced inputs of organic matter, increased decomposability of crop residues, and tillage effects that decrease the amount of physical protection to decomposition.

Soil organic carbon includes plant, animal and microbial residues in all stages of decomposition (Balesdent *et al*., 2000). Many organic compounds in the soil are intimately associated with inorganic soil particles. The turnover rate of the different soil organic carbon compounds varies due to the complex interactions between biological, chemical, and physical processes in soil. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored. The main factors acting on organic matter evolution concern the vegetation (residue input, plant composition), then climatic factors (temperature/moisture conditions) and soil properties (texture, clay content and mineralogy, acidity). The rate of SOM mineralization depends mainly on temperature and oxygen availability (drainage), land use, cropping system, soil and crop management (Lal *et al*., 2000).

2.2. Role of organic matter in soils

Soil organic matter represents a key indicator for soil quality, both for agricultural functions (i.e. production and economy) and for environmental functions (C sequestration and air quality). Soil organic matter is the main determinant of biological activity. The amount, diversity and activity of soil fauna and microorganisms are directly related to the organic matter. Organic matter, and the biological activity that it generates, have a major influence on the physical and chemical properties of soils (Robert, 1996b). Aggregation and stability of soil structure increase with organic matter content. These in turn increase infiltration rate and available water capacity of the soil, as well as resistance against erosion by water and wind. Soil organic matter also improves the dynamics and bioavailability of main plant nutrient elements.

2.3. Effect of tillage on soil organic carbon

Tillage has a long history dating back millennia, and aimed to give soil aeration and to control weeds. Tillage operations also stimulate N release from SOM, the increase in aeration of the soil and the intense disturbance is the main factors stimulating the mineralization of organic matter by the soil micro-organisms (mahdi *et al*., 2005). Losses of soil organic carbon (SOC) due to soil management in agricultural areas have been identified as a factor that accelerates the greenhouse effect, especially by emitting CO_2 in the atmosphere (La Scala *et al*., 2008). Smith *et al*. (2010) noted that the impact of tillage on the loss of SOC and associated emission factors under different management systems can be affected by the depth of tillage. Agricultural activities contribute with approximately 20 % to the global greenhouse gas emissions (Lokupitiya *et al*., 2006). No-till farming combined with the maintenance of crop residues on the soil surface has been identified as an important strategy for sequestering carbon from the atmosphere (Lal, 2007). Tillage induces the loss of C as CO_2 by breaking up soil aggregates and exposing the protected organic matter to microbes (Balesdent *et al*., 2000). Tillage also incorporates and mixes residues, improving aeration, which can lead to additional C losses by maximizing soil-residue contact, compared with no-residue incorporation (Jacinthe and Lal, 2005). Soil organic matter decay activate by tillage is related to soil temperature, soil moisture, and the amount and quality of soil organic carbon (Zhang *et al*., 2011; Schomberg *et al*., 1997). If minimizing soil disturbance decreases SOC decomposition rate, then this change in management practice would cause decreased transfer of C from soil to the atmosphere and can be a way of climate change mitigation (Baker *et al*., 2007). Under zero tillage SOC tends to be concentrated near the soil surface, because there is an absence of mixing or disturbance of the soil (Machado *et al*., 2003). As zero till maintain for long time Thus, accumulation of SOC occurs and decomposition of organic matter decreased, at the same time it decrease in the movement of C from soil to the atmosphere (Boddey *et al*., 2009).

2.4. Effects of crop residue on soil organic carbon

Increase in biomass both above ground biomass and root biomass induce the C input and considerable progress could be made in this connection, especially by selection of deep-rooting species and varieties. Crop residue management is another important method of sequestering C in soil and increasing the soil OM content (Lal, 1997). Generally, there is a linear relationship between the organic matter in the first 15cm of soil and the quantity of crop residues applied (FAO, 2001). Surface applied crop residues decompose more slowly than those that are incorporated by tillage, because they have less contact with soil microorganisms and soil water (mahdi *et al*., 2005). According to Angers *et al*. (1995) report, the conversion of maize residue C into soil organic matter in the 0 to 24cm layer was about 30 percent of the total input, even though there are qualitative differences between the residues type, which is the lignin content of the residue has a highly positive effect on the accumulation of SOM. Roots are very easily transformed into stable OM. Mulch farming and plant cover are specific land management practices allowing both coverage of the soil by specific plants, giving protection against erosion, and providing biomass residues to increase soil OM (FAO, 2001). To be completely effective, plant cover or mulch management should be carried out on site and in combination with conservation tillage (agro-biological management). A great variety of plant species can be used to cover the soil and it depends on the quality and quantity of the plant residues to induce the C storage in the soil (Andrews *et al*., 2001)

2.5. Soil organic carbon and soil texture

As Feizienė *et al*. (2010) revealed that soil texture and type of crop residue have a strong effect on soil respiration. Fine-textured soils have high water-holding capacity, potentially prolonging the availability of water in surface layers. Conversely, high in filtration rates on coarse-textured soils shift available water to deeper soil layers. Thus, the interaction of soil texture, SOM and plant cover may result in significant spatial and temporal variation in Soil respiration responses to precipitation pulse variability (Cableetal *et al*., 2008). Long-term conservation tillage management resulted in more uniform across-season soil CO_2 flux rates that were less affected by precipitation events (Bauer *et al*., 2006). Stabilization of clay surfaces has been recognized as a mechanism for storing organic matter in soils (Torn *et al*., 1997; Percival *et al*., 2000).

Clay particles saturated with multivalent cations tend to remain in a flocculated state reducing the exposure and mineralization of Organic Carbon adsorbed on clay particle surfaces or existing as globules between packets of clays within a clay matrix and changes in organic matter properties that correlate with soil texture (Percival *et al*., 2000). Carbon inventories are higher in the soils, which have higher clay content and higher fractions of clay associated with high organic matter. SOC is transformed by bacterial action and stabilized in clay or silt sized organomineral complexes (HF-OC) where the majority of SOC is found. The highest concentrations of SOC are associated <5µm mineral particles. Following the addition of simple substrates, new SOC is found to be associated with a range of mineral particle sizes. However, clay sized organomineral complexes often show greater accumulations and subsequently more rapid loss rates than in silt sized particles, indicating a higher stability of silt-SOC (Christensen, 1996).

2.6. Tillage and Crop Residue Effects on Soil Carbon Dioxide Emission

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere (NRC, 2010) .

An experiment was conducted by Mahdi *et al*. (2005) in relation to effect of tillage and crop residue on CO_2 emission, and treatment (no-tillage with and without residue, strip-tillage, deep rip, chisel plow and moldboard plow) effects on soil CO_2 emission were observed at almost all measuring times although CO_2 emission varied tremendously with time regardless of treatment. At Hour 0 measurement time, no-tillage with and without residue, strip-tillage, deep rip, and chisel plow treatments reduced CO_2 emission by 79, 79, 60, 50, and 14%, respectively, compared with moldboard plow immediately after tillage operations. The greatest reductions in CO_2 emission are associated with those tillage systems having less soil disturbance, such as the two no tillage treatments (Feizienė *et al*., 2010). Removal of crop residue from the soil surface under no-tillage did not alter CO_2 emission compared with no-tillage with residue at the measurement time of Hour 0. At the 2^{nd} hr measurement time, CO_2 emission from no-tillage with and without residue and strip-tillage are 43 to 58% less than from moldboard plow, while chisel plow and deep rip treatments have similar CO_2 emission as moldboard plow. Beyond 2 hr tillage operations, no-tillage with residue produces a significantly lower CO_2 emission than moldboard plow at all the measurement times. No-tillage without residue results in greater CO_2 emission than no-tillage with residue at the measurement times of Hour 4, 48, and 288.

The results generally confirm the potential of reducing tillage intensity and increasing crop residue on the soil surface in reducing soil CO_2 emission to the atmosphere. The maximum CO_2 emission from all tilled treatments (strip-tillage, deep rip, chisel plow, and moldboard plow) is observed immediately after tillage operations (i.e., at Hour 0 measurement time). Other experiments conducted similar to Mahdi by Jackson *et al*., (2003) and Roberts *et al*., (1990) concluded that the increase in soil CO_2 emission immediately after tillage operation was not due to the increase in microbial activities, but it was rather due to the increase in soil aeration that was induced by tillage disturbance. Cumulative CO_2 emission for the entire 20 days of tillage are 41, 26, 21, and 19% lower for no-tillage with residue, strip-tillage, deep rip, and chisel plow than with moldboard plow, respectively. Cumulative CO_2 emission from no-tillage without residue is 23% lower than that with moldboard plow, but 24% greater than the CO_2 emission from no-tillage with residue over the 20 days. Tillage operations may physically facilitate gas emission from the soil pores due to soil disturbance (Ellert *et al*., 1999; Mahdi *et al*., 2005). Crop residue on the soil surface with no-tillage contributes to the reduction of soil CO_2 emission by serving as a barrier for CO_2 emission from soil to the atmosphere, having a lower crop residue decomposition rate due to minimum residue-soil contact, and lowering soil temperature (Reicosky *et al*., 1999).

2.7. Relationship between CO_2 emissions and soil temperature and Soil moisture

Soil temperature and soil moisture are considered the most influential environmental factors controlling soil surface carbon dioxide exchange rate. These factors interact to affect the productivity of terrestrial ecosystems and the decomposition rate of soil organic matter, thereby driving the temporal variation of soil respiration (Wiseman, 2004). Root and microbial sources of CO_2 emission increased activity as a function of temperature (Boone *et al*., 1998) As a result, subsurface concentrations, and surface fluxes of CO_2 are a function of root and microbial production as well as a suite of other processes. Temperature is the best predictor of the annual and seasonal dynamics of the soil respiration rate and has positive relationship between CO_2 emissions and soil temperatures (Kudeyarov, 1998).

The temperature sensitivity coefficient for ecosystem respiration declined in association with reductions in soil moisture. Soil moisture was the dominant environmental factor that controlled seasonal and inter annual variation in total ecosystem respiration (Flanagan, 2005). The amount and distribution of precipitation is an important controlling factor of soil respiration (Lee *et al*., 2002). In dry conditions, root and micro-organism activity is typically low, resulting in low soil CO_2 efflux. Increasing the soil moisture normally increases the bio-activity in the soil. But if there is very high soil moisture, total soil CO_2 efflux is reduced, because of limited diffusion of oxygen and subsequent inhibition of CO_2 emissions. Furthermore, it was evidenced that the effect of precipitation on soil respiration stretched beyond its direct effect via soil moisture (Raich *et al*., 2002). Thus, it is important to understand which climatic factors control soil respiration and how these factors affect CO_2 emissions from soils (Reichstein, 2008).

3. Conclusion

Losses of soil organic carbon due to soil management in agricultural areas have been identified as a factor that accelerates the greenhouse effect, especially by emitting CO_2 in the atmosphere. The presence of crop residues on the soil surface influenced the magnitude of soil C and CO_2 emission in farming systems, especially after tillage operation, due to this and other factors are responsible to accumulate green house gas. Strategies aimed at reducing CO_2 in the atmosphere are mandatory. Therefore No tillage with and without crop residue is increase the soil carbon and decrease the emission of $CO_{2,}$ tillage frequency should be at the minimum condition which is conservation agriculture has spread where farmers have convinced by understanding of its benefits. These are including soil carbon sequestration in soils, tree planting, and ocean sequestration of carbon. Other technological strategies to reduce carbon inputs include developing energy efficient fuels, and efforts to develop and implement non-carbon energy sources. All of these efforts combined can reduce CO_2 concentrations in the atmosphere and help to alleviate global warming.

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