Applied Soil Ecology 89 (2015) 59–68

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

In-field management of corn cob and residue mix: Effect on soil greenhouse gas emissions

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ARTICLE INFO

Article history:
Received 18 April 2014
Received in revised form 31 December 2014
Accepted 8 January 2015
Available online 21 January 2015

Keywords:
Corn cob
Corn residue
CO_2
N_2O
Tillage
N fertilization

ABSTRACT

In-field management practices of corn cob and residue mix (CRM) as a feedstock source for ethanol production can have potential effects on soil greenhouse gas (GHG) emissions. The objective of this study was to investigate the effects of CRM piles, storage in-field, and subsequent removal on soil CO_2 and N_2O emissions. The study was conducted in 2010–2012 at the Iowa State University, Agronomy Research Farm located near Ames, Iowa (42.0°′N; 93.8°′W). The soil type at the site is Canisteo silty clay loam (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls). The treatments for CRM consisted of control (no CRM applied and no residue removed after harvest), early spring complete removal (CR) of CRM after application of 7.5 cm depth of CRM in the fall, 2.5 cm, and 7.5 cm depth of CRM over two tillage systems of no-till (NT) and conventional tillage (CT) and three N rates (0, 180, and 270 kg N ha^{-1}) of 32% liquid UAN (NH_4NO_3) in a randomized complete block design with split–split arrangements. The findings of the study suggest that soil CO_2 and N_2O emissions were affected by tillage, CRM treatments, and N rates. Most N_2O and CO_2 emissions peaks occurred as soil moisture or temperature increased with increase precipitation or air temperature. However, soil CO_2 emissions were increased as the CRM amount increased. On the other hand, soil N_2O emissions increased with high level of CRM as N rate increased. Also, it was observed that NT with 7.5 cm CRM produced higher CO_2 emissions in drought condition as compared to CT. Additionally, no differences in N_2O emissions were observed due to tillage system. In general, dry soil conditions caused a reduction in both CO_2 and N_2O emissions across all tillage, CRM treatments, and N rates.

1. Introduction

The dependency on fossil fuel in the United States (U.S.) has prompted the use of renewable sources of energy such as, biomass, solar, wind, geothermal, etc. Currently in the U.S., an estimated 170–256 million dry tons per year of corn (*Zea mays* L.) residue is potentially available for cellulosic ethanol production (U.S. tons; U.S. Department of Energy, 2011), which has the potential to reduce soil GHG (Dwivedi et al., 2009; Wilhelm et al., 2004; Graham et al., 2007). The cellulosic ethanol production from corn residue, which is a mixture of CRM (70% corn cob and 30% stover), has been used currently as a feedstock source by commercial ethanol plants in the U.S. (Schubert, 2006). However, field observations showed that storage and collection of CRM in the field caused detrimental effects to plant growth and development (personal observations of approximately 279 m^2 affected surface area, where CRM was piled and stored at different fields in northwest Iowa in 2009). Heavy machinery is used for piling and removing CRM, which can cause significant soil compaction, especially during wet conditions in the spring in Iowa. Therefore, piling and removal of CRM can lead to increase in soil compaction and bulk density (ρ_b), and affect soil diffusivities due to reduction in soil porosity (Wilhelm et al., 2004; Graham et al., 2007), N immobilization, plant growth, and soil GHG emissions (Chen et al., 2013).

Crop residue plays an important role in improving and maintaining adequate soil physical, biological, and chemical properties, which are essential in maintaining soil productivity (Karlen et al., 1994). Therefore, changes in management practices associated with crop residue can contribute to changes in the soil environment including soil GHG emissions (CO_2 and N_2O) (Cole et al., 1997; Smith et al., 2007). Some strategies to mitigate soil GHG emissions may include crop rotation, efficient N fertilizer management, and use of conservation tillage systems to sustain soil quality and crop yields (Paustian et al., 2000; Johnson et al., 2007). The reduction in tillage intensity by using NT is one option

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http://dx.doi.org/10.1016/j.apsoil.2015.01.007
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that can have a positive effect on reducing soil organic C and N mineralization, which can potentially lower soil CO_2 and N_2O emissions (Drury et al., 2006; Snyder et al., 2009). The reduction of soil GHG emissions under NT can be attributed to greater soil ρ_b at the soil surface, which reduces gas diffusivity and increases water content. These circumstances are favorable for anaerobic conditions resulting in denitrification processes and production of N_2O gas (Mosier et al., 2002). The use of NT results in less soil disturbance and increases residue cover creating wetter soil conditions. Therefore, NT is conducive to the increase of soil N_2O emissions, especially in poorly-drained soils that are susceptible to denitrification processes (Linn and Doran, 1984; MacKenzie et al., 1998; Mosier et al., 2002). In annual cropping systems such as continuous corn, which requires high N rates, the source and rate of N were significant factors in determining the severity of soil N_2O emissions (Bouwman, 1996; Pelster et al., 2011). However, the effects of N rates on soil CO_2 emissions were found to be variable (Al-Kaisi et al., 2008).

The storage of CRM in-field is a new practice, and there is limited research on the effect of CRM on soil GHG emissions. Nevertheless, in-field CRM storage can cause changes in soil organic C and N mineralization, thus, affecting soil GHG emissions (Cochran et al., 1997; Paustian et al., 2000; Mosier et al., 2002; Chen et al., 2013). Greenhouse gas emissions are mostly affected by biological processes such as, availability of C substrate, mineral N sources for nitrification or denitrification, and soil conditions including soil temperatures, soil water content, and oxygen availability (Butterbach-Bahl et al., 2013). These soil environment parameters can be influenced by type of tillage and affect soil C and N dynamics (Reicosky et al., 1997; Al-Kaisi and Yin, 2005; Al-Kaisi and Kwaw-Mensah, 2007). The effect of the storage and removal method of CRM on soil GHG emissions will depend heavily on the cropping system (Doran et al., 1984), climate, and soil type (Mu et al., 2008), which can be site specific. The objective of this study was to investigate the potential effect of storage and removal of CRM on soil GHG emissions and suitable management practices, such as tillage, N fertilization, CRM amounts left on the soil surface, and their interaction effects on soil GHG emissions. We hypothesized that changes in soil biological and physical properties during CRM storage and removal can create soil conditions that may increase soil GHG emissions.

2. Materials and methods

2.1. Experimental sites and treatments

The study was established in the fall of 2010 on a Canisteo silty clay loam (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls) and Harps loam (loam, mixed, superactive, mesic Typic Calciaquolls) soil association at the Iowa State University, Agronomy Research Farm located in Central, Iowa (42.0°′N; 93.8°′W). The average annual temperature and annual precipitation at the site for 2011 was 8.7 °C and 807 mm, respectively. In 2012, the average annual temperature was 11.4 °C and annual precipitation was 512 mm (Fig. 1). Before the study was established in the fall of 2010, the site was in a corn–soybean [*Glycine max* (L.) Merr.] rotation under conventional tillage, which was chisel plowed in the fall and disked in the spring. Source of N fertilizer used was liquid urea–ammonium nitrate 32% N (UAN), which was side-dress injected in May after planting using agronomic rates of 170 kg N ha^{-1} (Blackmeter et al., 1997). Phosphorus and potassium fertilizers were applied as needed to maintain optimum fertility

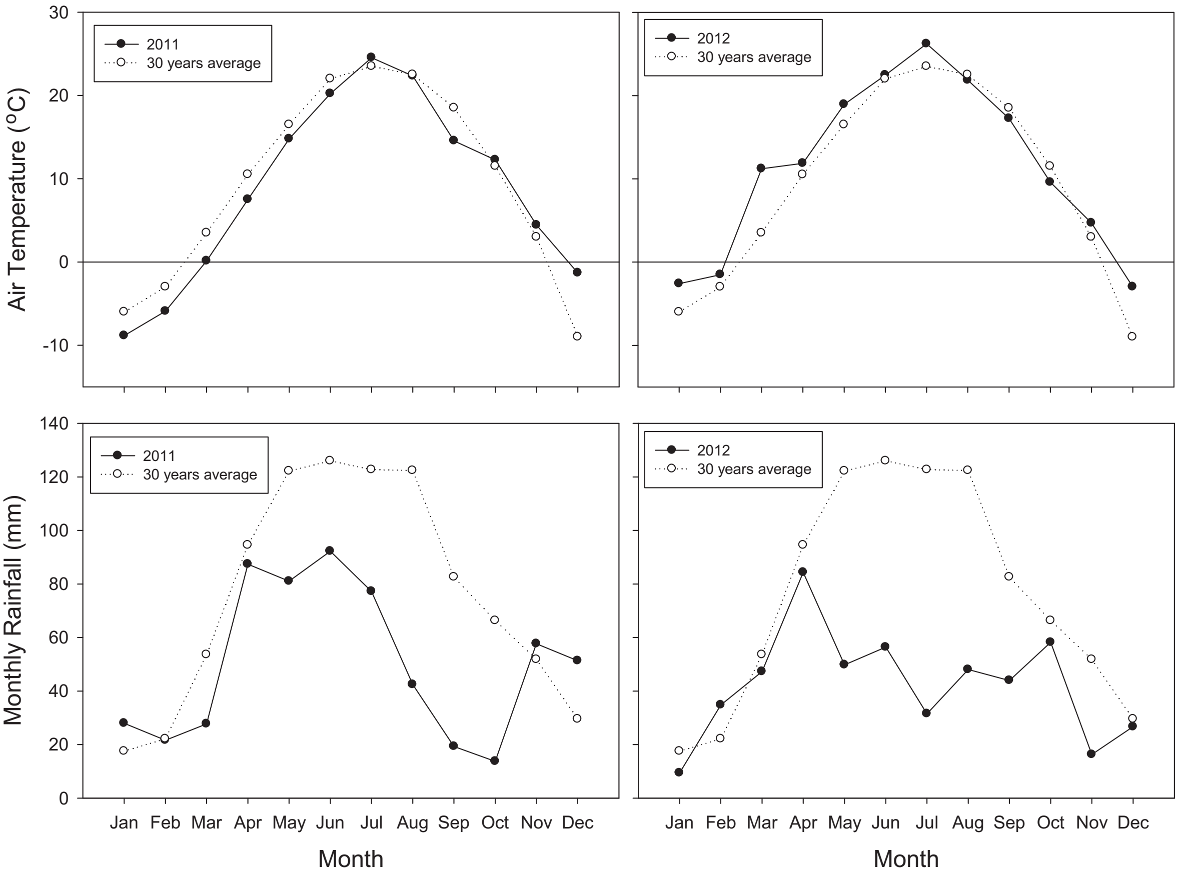

Fig. 1. Average monthly air temperature and rainfall for 2011 and 2012 growing seasons.