Waste Management 81 (2018) 202–210

Contents lists available at ScienceDirect

Waste Management

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

Effects of different agricultural organic wastes on soil GHG emissions: During a 4-year field measurement in the North China Plain

Zhejin Li [a,1], Dong Wang [a,1], Peng Sui [a], Pan Long [a,b], Lingling Yan [a,c], Xiaolong Wang [a,d], Peng Yan [a], Yawen Shen [a], Hongcui Dai [a], Xiaolei Yang [a], Jixiao Cui [a], Yuanquan Chen [a,*]

[a] College of Agronomy and Biotechnology, China Agricultural University, Beijing 100193, China
[b] College of Agronomy, Hunan Agricultural University, Changsha 410000, China
[c] Yiyang Agricultural Research Institute, Yiyang 413002, China
[d] College of Agronomy, South China Agricultural University, Guangzhou 510642, China

ARTICLE INFO

Article history:
Received 12 May 2017
Revised 4 September 2018
Accepted 5 October 2018

Keywords:
Soil GHG emission
Organic wastes
Emission factors
Characteristics of organic wastes
Cropping system
North China Plain

ABSTRACT

Large quantities and many varieties of agricultural organic wastes are produced in China annually. Applying agricultural organic wastes to soil plays an essential role in coping with the environmental pollution from agricultural wastes, solving the energy crisis and responding global climate change. But there is little information available on the effects of different agricultural organic wastes on soil greenhouse gas (GHG) emissions. The objectives of this study were to investigate and compare the impacts of different organic wastes on soil GHG emissions during a 4-year field experiments in the North China Plain, as well as analyze the influential factors that may be related to GHG emissions. The treatments were: crop straw (CS), biogas residue (BR), mushroom residue (MR), wine residue (WR) and pig manure (PM) returning to soil, as well as a control with no organic waste applied to soil but chemical fertilizer addition only (CF). The results showed that compared with CF treatment, organic material applied to soil significantly increased GHG emissions and emissions followed the order of WR(27,961.51 kg CO_2-eq/ha/yr) > PM (26,376.50 kg CO_2-eq/ha/yr) > MR(23,366.60 kg CO_2-eq/ha/yr) > CS(22,434.44 kg CO_2-eq/ha/yr) > BR (22,029.04 kg CO_2-eq/ha/yr) > CF(17,402.77 kg CO_2-eq/ha/yr), averagely. And considering the affecting factors, GHG emissions were significantly related to soil temperature and soil water content. Different organic wastes also affected soil total organic carbon (TOC), microbial carbon (MBC) and dissolved organic carbon (DOC) contents, which related to GHG emissions. Further analysis showed that characteristics of organic wastes affected GHG emissions, which included C-N ratio, lignin, polyphenol, cellulose and hemicellulose. Our study demonstrates that biogas residue returning to soil emitted minimum GHG emissions among these different types of organic wastes, which provided a better solution for applying organic wastes to mitigate soil GHG emissions.

1. Introduction

Global climate change is arguably the most urgent environmental challenge confronting society. Atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the most potent long-lived greenhouse gases (GHG) that contribute to global warming. Agriculture, which contributes to about 10%–12% of total global anthropogenic GHG emissions (IPCC, 2007), is recognized as the important source of GHG emissions. CO_2 and CH_4 emissions in cropland are derived from a variety of practices in the agricultural sector, including soil tillage, soil drainage, rice management, biomass burning, flooding, and the use of fertilizers and residues (Smith et al., 2008; West and Marland, 2002). N_2O has a global warming potential 298 times greater than CO_2, over a hundred year time horizon, which is derived from soil microorganisms activities, such as nitrification and denitrification processes (IPCC, 2007), which can be reduced by the field management practice like, no-tillage (Van Kessel et al., 2012), straw return (Yao et al., 2017).

The livestock sector contributes 40–50% of agricultural GDP, but also should be responsible for greenhouse gas emissions of 5.6–7.5 Gt CO_2-eq/yr; and in order to mitigate global warming potential, it's important to reduce emissions from manures or wastes and

* Corresponding author at: College of Agronomy and Biotechnology, China Agricultural University, No. 2 Yuanmingyuan West Road, Haidian District, Beijing 100193, China.

E-mail address: rardc@163.com (Y. Chen).

[1] The first and second author have the same contribution to this article.

https://doi.org/10.1016/j.wasman.2018.10.008
0956-053X/

to promote carbon sequestration (Herrero et al., 2017). Organic wastes have already been widely used in China, since they carry a full range of nutrients and are rich in biologically active substances (Zhao et al., 2009), which is not only helpful to improve soil fertility and crop quality but also beneficial to protect the environment. Adding them to the farmland, one the one hand, they can supply various macro-nutrients and micro-nutrients, improve soil chemical and physical properties and promote plant growth (Zhao et al., 2009); on the other hand, the microbial biomass carbon and enzymatic activity can be increased. And long-lasting application of organic wastes showed that they can increase the soil organic carbon (Diacono and Montemurro, 2010). Thus, organic residues can be used as soil organic amendments, which are available from a wide range of production process, such as crop production, animal production, food and energy processing and municipal sources.

Plenty of benefits applying organic wastes to soil have been reported as mentioned above, however, the emissions of GHGs become remarkable during the organic wastes production and application, such as the compost (Sommer et al., 2009; Leytem et al., 2011) and the incorporation of organic wastes to soil. Previous research mainly concentrates on the comparison of GHG emissions between certain kinds of organic wastes or between chemical fertilizer and organic fertilizers. Generally, organic wastes can certainly enhance GHG emissions compared with inorganic fertilizers (Ding et al., 2007; Verhoeven and Six, 2014). Nonetheless, via a more comprehensive and useful method-life cycle assessment (LCA), which can analyze potential environmental impacts throughout a product's life cycle including the supply chain and downstream processes (ISO, 2006), some researches point out that GHG emissions avoid the consequence of the "no" use of chemical fertilization. For example, Moore et al., (2017)reported that replacing chemical fertilizers with vinasse and filter cake is beneficial to the environment since it reduces GHGs emissions in the entire process of ethanol production.

In addition, a large amount of agricultural wastes is produced in China not only with tremendous quantity but also with multiple species. According to National Development and Reform Commission of China (NDRC), the theoretical volume of crop straw resources reached to 863 million tons in 2011, and the annual livestock manure production was estimated to be 3 trillion tons, but quite a number of them were wasted or non-recycled (NDRC, 2012). Besides, except the common wastes such as crop straw and livestock manure, with the development of diversified agricultural production, diverse organic wastes were produced in China, such as biogas residues, mushroom residues and wine residues. Nowadays, biogas has become an important component of sustainable development because it's attributable to the reduction of environment pollution and the alleviation of energy shortage effectively. By the end of 2015, the total biogas yield was 15.8 billion m^3 in China which means that a great deal of biogas residue has been produced equivalently (NDRC, 2017). Food and Agriculture Organization (FAO) estimated the production of mushrooms and truffles reached to 6.4 billion t in 2008 and China contributed more than 70% of world's total production of mushrooms, which also created huge mushroom residues (FAOSTAT, 2012). And due to the longtime drinking history in China as well as the growth of population, it brings not only the increase of wine consumption, but also the tremendous wine residue from brewing at the same time.

The area of North China Plain (NCP) is about 14 million hectare located in Hebei, Shandong, and Henan Provinces (account for 1.5% of the country), in which the area of approximate 7.7 million hectare are currently under cultivation (account for 6.4% of the country); and the population is approximate 120 million (account for 8.7% of the country). As an important center of agricultural production, it accounts for 61% of the country's wheat production and over 30% of the maize production in China. Meanwhile, the massive grains production of brings a lot of agricultural wastes. Since we know that there are indeed many benefits that organic wastes as soil amendments can bring to us, Chinese government encourages farmers to reuse and recycle wastes in the agricultural production to achieve the environmental-friendly and sustainable development of agriculture. However, there is still little scientific information about the effects of GHG emissions from different agricultural wastes. Thus, this paper aims at the investigation of GHG emissions and the global warming potential induced by different types of organic wastes after adding to the farmland. And in this study, through a 4-year experimental measurement with summer maize-winter wheat rotation, which is a mainly cropping pattern in NCP, the dynamic and total emission of main GHG, i.e. CO_2, N_2O and CH_4 were analyzed, along with their influential factors, which could also be functional in the construction of essential data base guiding for GHG mitigation in agriculture processes, especially for agricultural waste management.

2. Materials and methods

2.1. Experimental site

The experiment was conducted at the Wuqiao Experimental Station in Wuqiao County, Hebei Province (37°41′02″N, 116°37′23″E). The mean annual temperature at the site is 10–12 °C, sunshine duration is 2724 h and accumulated temperature (≥0 °C) is 4826 °C. The average annual rainfall during the last 20 years was 560 mm. Generally, 60–70% of the annual precipitation occurs from June to August, which covers most of the maize season. The soil at the experimental site is classified as alluvial salt aquic soil and classified as silty loam (IUSS Working Group WRB 2006). The initial texture and principal properties of experiment soil for 0–10 cm and 10–20 cm depth are available in Table 1.

2.2. Experimental design

The experiment was established in October 2012. Experimental plots (2 × 2 m) were arranged in a randomized complete block design with three replications per treatment. This micro-plot trial is beneficial to detect the impact factors of different organic wastes returning to field as precisely as possible. Winter wheat (*Triticum aestivum L.*, from the middle of October to early June) variety Jimai 22 was sown at a rate of 300 kg/ha, and summer maize (*Zea mays L.*, from early June to the middle of October) variety Zhengdan 958 was seeded at a rate of 45 kg/ha. Following the fertilizer strategy of many longtime experiment of organic wastes, all plots received a broadcast fertilizer application of P_2O_5 26 kg/ha (diammonium phosphate) and K_2O 124 kg/ha (potassium sulfate) before seeding and pure nitrogen 150 kg/ha (urea) before seeding and at the jointing stage separately in every growing season.

There were five treatments of different organic wastes returning to fields: crop straw (CS), biogas residue (BR), mushroom residue (MR), wine residue (WR) and pig manure (PM), and one treatment with only chemical fertilizers (CF). Although in actual farming practices, nutrition supply, such as nitrogen, also is an important topic, since we wanted to focus more on soil carbon storage, soil GHG emissions and the entire carbon cycle of croplands under the circumstances of organic wastes inputs, the amount of organic wastes returned to the field should be equivalent as far as carbon amount in every growing season, which means that organic wastes carbon was needed to be returned as the same amount as the harvesting, based on themselves carbon content and quantities. Therefore, we calculated that the actual amount of C