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Review

Role of organic amendment application on greenhouse gas emission from soil

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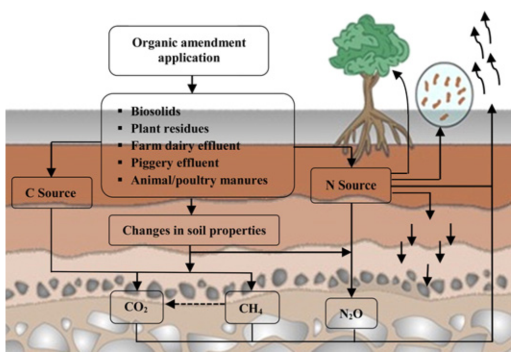
HIGHLIGHTS

- ► A comprehensive overview for the first time on GHG emission from organic amendments (OAs)
- ► The amounts of OAs and their carbon and nutrient value are quantified.
- ► The potential volumes of GHG produced from land application of OAs are quantified.
- ► The processes by which GHGs are emitted from soil are described.
- ► Management strategies to mitigate GHG emission from OAs are discussed.

GRAPHICAL ABSTRACT



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ABSTRACT

Globally, substantial quantities of organic amendments (OAs) such as plant residues (3.8×10^9 Mg/yr), biosolids (10×10^7 Mg/yr), and animal manures (7×10^9 Mg/yr) are produced. Recycling these OAs in agriculture possesses several advantages such as improving plant growth, yield, soil carbon content, and microbial biomass and activity. Nevertheless, OA applications hold some disadvantages such as nutrient eutrophication and greenhouse gas (GHG) emission. Agriculture sector plays a vital role in GHG emission (carbon dioxide— CO_2, methane— CH_4, and nitrous oxide— N_2O). Though CH_4 and N_2O are emitted in less quantity than CO_2, they are 21 and 310 times more powerful in global warming potential, respectively. Although there have been reviews on the role of mineral fertilizer application on GHG emission, there has been no comprehensive review on the effect of OA application on GHG emission in agricultural soils. The review starts with the quantification of various OAs used in agriculture that include manures, biosolids, and crop residues along with their role in improving soil health. Then, it discusses four major OA induced-GHG emission processes (i.e., priming effect, methanogenesis, nitrification, and denitrification) by highlighting the impact of OA application on GHG emission from soil. For example, globally 10×10^7 Mg biosolids are produced annually which can result in the potential emission of 530 Gg of CH_4 and 60 Gg of N_2O. The article then aims to highlight the soil, climatic, and OA factors affecting OA induced-GHG emission and the management practices to mitigate the emission. This review emphasizes the future research needs in relation to nitrogen and carbon dynamics in soil to broaden the use of OAs in agriculture to maintain soil health with minimum impact on GHG emission from agriculture.

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Contents

1. Introduction

Agriculture is the major land use across globe with 1.2–1.5 billion ha as crop land and 3.5 billion ha as pasture land (Howden et al., 2007). Rotation of crops with regular fallow periods, and animal manure or plant residue application were practiced in traditional agriculture to maintain soil fertility and health, thereby supporting crop production. However, to meet projected increase in food demand due to an exponential growth in human population, these traditional methods have been replaced by application of mineral fertilizers. Commercially available mineral fertilizers possess advantages such as high solubility, facilitating the nutrient uptake by plants, and better means of storage and handling (Jensen et al., 2011). However, high inputs of these chemical fertilizers contribute to soil degradation, damage to the environment, and loss of biodiversity. Most importantly, these chemicals have contaminated groundwater in many regions making it unfit for human consumption (Jiang and Yan, 2010).

Considering the global demands and increasing cost of mineral fertilizers, use of organic amendments (OAs) including manures, composts, crops residues, and biosolids is rapidly increasing and their share of agricultural land and farms continues to grow in many countries. For example, globally, about 32.2 million ha of agricultural land was managed organically using mainly OAs by more than 1.2 million growers. Oceania, Europe, and Latin America are the regions with the largest organically managed land areas (Willer et al., 2009). Application of OAs is regarded as one of the most promising options to increase farmers' income by restoring soil fertility and at the same time to protect the environment. Organic agriculture possesses several advantages such as improving plant growth and yield, soil carbon (C) content, and microbial biomass and activity, and preventing desertification by improving soil structure and fertility. Nevertheless, OA applications possess some disadvantages such as nutrient eutrophication and greenhouse gas (GHG) emission (Fig. 1).

Agriculture plays a major role in the global fluxes of the GHG including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Agriculture contributes up to 10–12% of total global anthropogenic emissions of GHG, and OAs provide a major source of all these gases (IPCC, 2007). Though CH_4 and N_2O emissions are far less in quantity in the atmosphere, they have a much more adverse impact on the climate when compared to CO_2 (Rodhe, 1990). Although a number of reviews have examined the emission of GHG from agricultural soils as impacted by fertilizer application, there has been no comprehensive review on the role of OA application on GHG emission from agricultural soils. The present review focuses on GHG emission from the soils treated with OAs. The article first outlines the various OAs used in agriculture and their benefits in agriculture, and then discusses the processes involved in the OA-induced GHG emission from soil. The review also underlines the influence of OAs on GHG emission from soil, factors affecting gas emission, and the management practices that have been used to mitigate the emission. Future research should aim at maximizing the benefit of OA application to restore soil fertility and health and at the same time should explore strategies to mitigate GHG emission from OAs.

1.1. Sources and types of organic amendments used in agriculture

Organic amendments used in agriculture include biosolids, animal manures, municipal solid wastes (MSW), yard waste composts, crop residues, seaweeds, blood and bone meal, and humic substances. A large range of OAs has become commercially available in the market which highlights the booming of organic farming systems and the value of these amendments in improving soil quality. A number of