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Greenhouse gas and ammonia emissions and mitigation options from livestock production in peri-urban agriculture: Beijing – A case study

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ABSTRACT

Livestock production in peri-urban areas constitutes an important sub-sector of the agricultural production system in China, and contributes to environmental degradation and local air borne pollution contributing to smog. As a result, local policies are being implemented to safeguard the environment. However, there has been little attempt to quantify the impact of environmental policies on livestock production structure, spatial distribution and their related greenhouse gases (GHGs) and ammonia (NH_3) emissions. Here, we calculated the inventories of GHGs and NH_3 emissions for 2010 and 2014 for peri-urban livestock production in Beijing, using reliable spatially explicit data, which was collected from 1748 industrial farms in 2010 and 2351 industrial farms in 2014, including pig, dairy, beef cattle, poultry and sheep farms. Our estimates indicated that total industrial livestock production increased by 17% between 2010 and 2014, even under the more strict environmental protection polices, with farm size decreasing by between 7% and 47%. Up to 50% of the industrial livestock farms have remained in operation, with the rest closing down or being moved to other regions. Following this trend, total GHGs emission decreased from 5.0 to 4.5 Tg CO_2-eq between 2010 and 2014. Most of the GHGs emission reduction was due to the lowering of energy related carbon dioxide (CO_2) emission in 2014. Total NH_3 emission decreased from 102 to 96 Gg between 2010 and 2014, mainly due to more stringent environmental regulations for new and extended farms (increased in farm size), e.g. Discharge standard for pollutants for livestock and poultry breeding. Our study identified that GHGs and NH_3 emission hotspots were concentrated in suburban areas (around the city centre and with less agricultural resource and population density) in 2010. However, between 2010 and 2014 these hotspots moved to the exurban plain and mountain area following the closure or sub-division of intensive farms in suburban regions and construction of new and small farms in exurban areas (around the suburban and with more agricultural resource and lower population density). Scenario analysis suggests that total GHGs emission can be reduced by up to 1.0 Tg CO_2-eq (23% of total livestock sector emissions) in Beijing, using a combination of modifications of farm type, livestock diet and manure management. The integrated scenario can reduce CH_4, N_2O and NH_3 emissions by 27%, 9% and 35%, compared to the reference scenario. Within this short period of time (5 years), policies have had direct impacts on peri-urban livestock production in Beijing, resulting in marked changes in the structure of different livestock sectors, as well as the GHGs and NH_3 emission inventories and their spatial distribution. Our analysis clearly shows that the success of these (and future) polices relies on optimizing spatial management of new livestock production systems. Policy and farmer guidance should focus on optimizing livestock diet and on-farm manure management, industrial production systems and the pig and poultry sectors in peri-urban regions.

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1. Introduction

Rapid development of urban agriculture is associated with greenhouse gases (GHGs) and ammonia (NH_3) emissions and climate change (Broto and Bulkeley, 2013). Global atmospheric concentrations of the most important gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and ammonia (NH_3) have increased significantly in the last 150 years (Monteny et al., 2006; IPCC, 2014). Livestock farming systems are major source of trace gases contributing to atmospheric pollution locally and globally. The greenhouse gas emissions of livestock production and its by-products accounted for 18% of global total emissions (IPCC, 2014; Appuhamy et al., 2016). The 2nd National Climate Change Information Bulletin of China estimated that greenhouse gas emissions from agricultural activities was about 819 Tg of CO_2-eq, and that enteric fermentation and manure management contributed 54% of total agriculture GHGs emission (MNDFC, 2013). Therefore, gaseous emissions from livestock production must be better quantified to provide underpinning evidence for country- and regionally-specific inventory compilation, and for the prioritisation of mitigation strategies.

An urban livestock system is characterized by a large variation of livestock production systems that occur in and around densely populated areas and that strongly interact with the surrounding. Due to certain conditions, e.g., higher human population density, higher demand for livestock products, and increased industrialization and urbanization, the environmental impact of peri-urban livestock production has become more significant (Chadwick et al., 2015; Ma et al., 2014a, 2014b). During the period of 12th Five-Year plan (2011–2015), agricultural pollution sources were incorporated into the total control management system of China. Within this, large scale intensive livestock farms and collective feedlots have become the main focus for targeted mitigation. Meanwhile, some studies have shown high losses of nutrients around large cities (Shao et al., 2006; Ma et al., 2012), and that manure may need to be exported from peri-urban areas in the future to limit the effects on the environment, if livestock production continues to grow (Jia et al., 2015). Therefore, there is a need to focus more on characteristics of urban livestock production and its impact on the urban environment. In the last decade, many studies have reported on GHGs emission from livestock production based on national statistical data, and individual farm data (Garnett, 2007, 2009; Nguyen et al., 2010; Lesschen et al., 2011; Weiss and Leip, 2012; Bellarby et al., 2013; Appuhamy et al., 2016; Owen and Silver, 2015). However, due to limited availability of information from livestock systems at the farm- and regional level, accurate and quantitative GHGs and NH_3 inventories are scarce (Liang et al., 2013). Therefore, it is of great importance to quantify the GHGs and NH_3 emission of livestock production systems in urban and peri-urban areas, and to understand the spatial and temporal dynamics of these gaseous emissions.

Hence, the aim of this study was to quantify the changes in gaseous emissions from livestock farms in peri-urban areas of a rapidly growing city. We used Beijing as a case study, using the data collected from 1748 farms in 2010 and 2351 farms in 2014, to highlight the hotspots of GHGs and NH_3 emission and to estimate the potential of various mitigation strategies in peri-urban livestock production in the future. Scenario analysis was based on empirical data and modelling. In Beijing, livestock production in the urban center area is prohibited, however peri-urban livestock production is common. So there is no livestock production in urban center area. Therefore, although we have studied urban livestock in this paper, it is actually the study of peri-urban livestock production. Specific objectives were:

(1) to generate inventories of gaseous emissions (CH_4, CO_2, N_2O and NH_3) from large livestock production systems in the peri-urban area of Beijing during a period when environmental policies were introduced (2010–2014);
(2) to understand the spatial and temporal dynamics of gaseous emissions (CH_4, CO_2, N_2O and NH_3) from livestock production and highlight the hotspots of emission in peri-urban areas;
(3) to evaluate the potential of various mitigation measures and policy options for decreasing gaseous emissions from peri-urban livestock production systems.

2. Material and methods

2.1. System boundary

The system boundary of this research covered the production processes from “cradle” to “farm-gate” of livestock production systems, and the total GHGs emission include: (1) Feed production and processing: direct and indirect emission of N_2O in the process of N fertilizer manufacture and following application for feed production; NH_3 emission from N fertilizer application; fossil fuel CO_2 emissions from the manufacture of plastic sheeting and pesticides, and application of urea during feed production, machinery use during feed production, such as ploughing, seeding and harvesting; (2) CH_4 emission from enteric fermentation and manure treatment; direct and indirect N_2O emission from the manure management chain (housing, manure storage and treatment); CO_2 emissions from energy generation and consumption during animal production, such as electricity, coal, gasoline; (3) direct and indirect emission of N_2O from manure applications to cropping land (after manure has left the livestock farm); CO_2 emission through energy consumption during manure application (Fig. 1).

The study area is the capital of China – Beijing city. The whole Beijing city is divided into an urban center area (zone 1) and a peri-urban area. Peri-urban areas comprise three parts: the suburban area (zone 2), exurban plain area (zone 3) and exurban mountain area (zone 4) (Fig. 2). In total, seven animal categories were considered: pig, dairy, beef cattle, layer, broiler, duck and sheep. For each animal category, four farm classes were distinguished, namely traditional farming households, small farms, medium farms and intensive farms (SI). The traditional farming households produced animal feed themselves on their own land, and the industrial farms (small, medium and intensive farms) were landless, so all the feed was purchased from off-farm sources. Small household farms were more wide spread through the whole of Beijing except the urban center, and most of them were not regulated by policy, and not registered in the monitoring system. However, the industrial livestock production systems were registered in the system and more influenced by the policy. In this study, there were 1748 industrial

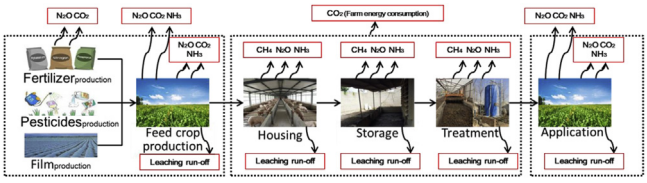

Fig. 1. Illustration of the system boundary used in this study. The emission from feed production, housing, manure storage and manure treatment, the key stages of animal production systems. Emissions inside of the dotted line are the local GHGs (CH_4, CO_2 and N_2O) and NH_3 emission for Beijing. Emission outside of the dotted line are the external GHGs and NH_3 emissions.