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Greenhouse gas emission of pastoralism is lower than combined extensive/intensive livestock husbandry: A case study on the Qinghai-Tibet Plateau of China☆

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ABSTRACT

The increasing demand of livestock products and production efficiency of livestock husbandry, and restoration of grassland ecosystem have been inducing the rapid transition of livestock husbandry systems from pastoralism into intensive systems. Such transition has been resulted in changes in the greenhouse gas (GHG) emissions, though it is rarely studied, especially in the pastoral area of China. Aimed to address this question, on the Qinghai-Tibet Plateau we selected Chanaihai village as the pastoralism system, and Guinan Grassland Development Limited Company as the combination of extensive and intensive livestock husbandry system, to compare the GHG emission between the two systems using life cycle assessment method. Our results showed that the GHG emission intensity both in per unit of area and per unit of carcass weight in the combined extensive/intensive livestock husbandry were higher than the pastoralism, indicating that the shift into the combined extensive/intensive livestock husbandry system increased the GHG emission. Such results could be attributed to the lower soil carbon uptake and higher GHG emission derived from the external inputs such as seed, diesel, and electricity in the combined extensive/intensive system. These findings demonstrated that the ongoing transition in the pastoral area of Qinghai-Tibet Plateau may be inappropriate under the background of global GHG mitigation. As suggestions, we argued that reduction in the manure combustion and increase in soil carbon uptake could be effective measures to reduce the GHG emission intensity of livestock husbandry.

1. Introduction

In 2006, the book Livestock's Long Shadow published by FAO reported that global livestock husbandry contributed an estimated 18% of global anthropogenic greenhouse gas (GHG) emissions (Steinfeld et al., 2006), which have become the main emission sources (Hristov et al., 2013; Herrero et al., 2016). Meanwhile, the increasing demands for meat and dairy product have induced the rapid development of livestock husbandry, especially in the developing countries (Thornton, 2010; Gerber et al., 2013a,b), that further increased the global GHG concentrations (Hristov et al., 2013; Herrero et al., 2016; Pardo et al., 2016). Therefore, mitigation strategies of GHG emission in livestock husbandry have been a focus of attention worldwide (Godfray et al., 2010; Soussana et al., 2013; Caro et al., 2014; Herrero et al., 2016).

Selecting an appropriate assessment method becomes essential to evaluate whether or not GHG mitigation strategies of livestock husbandry are economically feasible, effective and sustainable (Robèrt, 2000). With respect to the methods applied in this area, the life cycle assessment (LCA) is regarded as the scientifically robust methodology to evaluate the GHG mitigation measures of livestock husbandry (Robèrt, 2000; Prado et al., 2013; Gerber et al., 2013a,b; Huerta et al., 2016), and have been widely used to evaluate the GHG emission intensity of different livestock husbandry systems (Pelletier et al., 2010; Peters et al., 2010; Nguyen et al., 2010; Dick et al., 2015; Cerri et al., 2016; Ogino et al., 2016). LCA is a methodology for assessing the environmental impacts associated

☆ Combined extensive/intensive livestock husbandry is a production mode that part of livestock feed on higher quality forage in the feedlot, and the rest livestock are still grazing in the pasture.

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with the whole process from raw material extraction to products and to final waste disposal. On the one hand the LCA is able to quantify the emissions from production life cycles for comparison with other systems. On the other hand it is able to identify system components to maximize efficiency and/or minimize environmental impacts (ISO, 2006).

The FAO's Livestock's Long Shadow divided the livestock husbandry production systems into extensive (pastoralism) and intensive livestock husbandry (including both of combined extensive/intensive livestock husbandry and intensive livestock husbandry). The extensive livestock husbandry accounted for 13% of the world total anthropogenic emissions, while the intensive livestock husbandry accounted for 5%, indicating that the GHG emission in the extensive systems was higher than intensive (Steinfeld et al., 2006). Studies argued that productivity levels of the extensive system were relatively lower and emission intensities were correspondingly higher (Opio et al., 2013; Gerber et al., 2013a,b), so intensification of production system was regarded as the effective way for both increasing the production level and reducing the GHG emission intensity. Consequently, the transition from extensive to intensive has become the mainstream recommendation (Prado and Scholefield, 2008; Pelletier et al., 2010; Peters et al., 2010; Steinfeld and Gerber, 2010; O'Brien et al., 2011; Stackhouse et al., 2012; Cohn et al., 2014; Ruviaro et al., 2014). However, there were some researchers who had different views on the above conclusions. Rotz et al. (2010), Soussana et al. (2010), Foley et al. (2011), O'Brien et al. (2012), Bellarby et al. (2013), Soussana and Lemaire (2014) and Buller et al. (2015) argued that even though intensive system reduced the enteric methane emission through feeding higher quality forage in comparison with extensive system, the GHG emission intensity in intensive system was still higher than of the extensive. This was because, first, the additional external inputs including forage, fertilizer and electricity in the intensive system increased the GHG emission intensity (Ogino et al., 2016); and second, the more important reason was that previous studies did not consider the difference of soil carbon uptake between natural rangeland and artificial grassland (Gerber et al., 2013a,b; Dick et al., 2015; Ogino et al., 2016). In fact, some studies have proven that the extensive livestock grazing system on the natural rangeland had lower GHG emission intensity when the soil carbon uptake was taken into account in the emission inventory (Schils et al., 2005; Hacala et al., 2006; Pelletier et al., 2010; Veysset et al., 2010; Schönbach et al., 2012). Some researchers further pointed out that the GHG emission intensity in the intensive system was much more than the extensive if the loss of soil carbon caused by the change of land use to cultivate artificial forage in the intensive system was considered (Burney et al., 2010). Oppositely, some other researches pointed out that even if taking the soil carbon uptake into account, the GHG emission intensity in the extensive system was higher than the intensive, largely attributing to the decrease of soil organic carbon in the extensive livestock grazing (Bellamy et al., 2005). These previous studies indicated that it was still in debate whether the GHG emission intensity in extensive system was lower than the intensive or not, and it largely depended on the external inputs and soil carbon uptake that were of great significance for the both systems.

Following the global trend, China also has been promoting the transition from pastoralism into intensive livestock husbandry. About 42% of territory in China is natural rangeland, covering a total of 393 million hectares, where the most widespread land use system was traditional pastoralism (Ministry of Agriculture, 2007). The traditional pastoralism is regarded as extensive, fragile and economically inefficient. Moreover, 90% of China's rangelands, as is reported, have been degraded to some degree, which has been attributed to overgrazing under pastoralism (Ministry of Agriculture, 2007; Hilker et al., 2014). In order to improve the livestock husbandry production efficiency and restore the rangeland ecosystem, the governments have developed a series of policies and measures to promote the transition from pastoralism to intensive system. Therefore, it is of great significant to assess the impact of changes of livestock production system on the GHG emission intensity (Arsenault et al., 2009; Belflower et al., 2012; O'Brien et al., 2012; Ruviaro et al., 2014; Ogino et al., 2016). To our knowledge, only Schönbach et al. (2012) systematically analysed the GHG emission under different grazing intensity in the pastoral area of Inner Mongolia. However, how does such transition affect the levels of GHG emission intensity from livestock husbandry yet needs further study, especially in the pastoral areas of Qinghai-Tibet Plateau.

Pastoralism has been the main utilization mode of rangeland in the pastoral regions of the Qinghai-Tibet Plateau. In 2007, the governments initiated to practice intensive livestock husbandry. The Guinan Grassland Development Limited Company is one such example. Our study select Chanaihai Village as the pastoralism system, and Guinan Grassland Development Limited Company as the combination of extensive and intensive livestock husbandry system to assess, quantify and compare the GHG emission intensity using life cycle assessment methods (LCA), providing case-based evidences for development of low-carbon livestock husbandry in the region.

2. Materials and methods

2.1. Case study sites

The two study sites are located in Guinan county (100°75′E, 35°38′N) in the southeast region of Qinghai Province, P.R. China. The rangelands in this region are a mix of alpine meadow and alpine steppe with average elevations reaching 3200 m. The average annual precipitation in this region is 403.8 mm, while annual evaporation is 1378.5 mm and annual average temperature stands for 2.3 °C. Drought, snow disasters, frosts and sandstorms are the major natural disasters.

Chanaihai Village, one of the case study sites, has a total of 431 households with population around 2000. The village has 18,779 ha of rangelands supporting 83,701 sheep units including 63,701 sheep and 4000 yaks (one yak is equal to 5 sheep) in 2014. The village applied livestock mobility between four seasons with spring (April 15th to May 31st, 46 d), summer (June 1st to August 15th, 75 d), autumn (August 16th to October 15th, 61 d) and winter pastures (October 16th to April 14th of next year, 182 d). These different seasonal pastures provide the needs of livestock production all over the year.

Guinan Grassland Development Limited Company, a national demonstration area of intensive livestock husbandry system, is a combined system including rangeland, feedlot, artificial grassland, forage processing plant and organic fertilizer processing plant. There are 15,800 ha of rangelands and 2000 ha artificial grassland supporting 80,000 sheep. The rangeland is utilized for grazing which is similar to the pastoralism system. From August to October, nevertheless, 2 year-old and 3 year-old castrated rams that account for 1/3 of the herd population are fed in the feedlot using the fodder while the rest sheep are still grazing on the rangeland. *Elymus nutans* was planted in the artificial grassland. In March and April of every year, the 1175 kg/ha of organic fertilizer with 3.33% nitrogen was applied to the artificial grassland. The forage cultivation is rain feed.

2.2. System boundary

Definition of system boundary is an important step in LCA that