Research progress on soil methane uptakes in different land-use change

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Abstract. Land-use changes from the conversion of grassland and cropland are typical agricultural production mode that constitute one of the important sources of atmospheric methane(CH_4). Traditional grasslands have been experiencing conversion to croplands for pursuing higher economic benefits over the past decades in the arid and semi-arid lands of Asia. How the land-use changes in grasslands conversion to croplands altered the soil properties and the CH_4 uptakes remains unknown. Articles retrieved from SCI periodicals are summed up and refined to find the effects on the CH_4 uptake in the land-use change. In order to set up the basis on measures to mitigate greenhouse gas emissions. The results of this study suggest that The production mode of land-use change that traditional grasslands was converted into croplands for pursuing higher economic benefits over the past decades would also probably lead to a higher ecosystem CH_4 uptake rate and needs to be stopped in the arid and semi-arid lands of Asia.

1. Introduction

Methane(CH_4) is the second most important greenhouse gas in the atmosphere after carbon dioxide (CO_2). The atmospheric concentration of CH_4 has been increasing by 0.3%·year^{-1}[1]. Although the main sink for atmospheric CH_4 is its oxidation in the troposphere by hydroxyl(-OH), aerobic soils are the only biological sinks for atmospheric CH_4 with an estimated global sink of 20-45 Tg CH_4·year^{-1}[2]. Temperate steppe soils are known to function as a significant sink for atmospheric CH_4[3].

2. Basic situation of temperate steppes

The temperate steppes account for approximately 80% of Chinese grasslands[4], of which the grasslands of Inner Mongolia are an important component.

2.1Inner Mongolia steppes

The transition from livestock grazing to farming causes changes in land-use practice. The grassland in Inner Mongolia is a typical Leymus chinensis temperate steppe, where land-use types are often diverse with frequent changes. The area of the plowed grasslands conversion to croplands is 1.2 million ha.

2.1.1 Geographical sites. The study site is located at The National Field Station of the grassland ecosystem in Inner Mongolia(41°49′ 52″ N, 115° 13′ 26″ E). The station is positioned on the south side of the Xilin River that ranges in elevation of 1400 m above sea level in northern China.

2.1.2 climate. The area has a semi-arid temperate climate with a mean annual temperature of 1.6ºC and a mean monthly temperature that raries from -17.6ºC in January to 17.8ºC in July. The mean annual precipitation is 400 mm, most of which occurs from late April to early October.

2.1.3 Characteristics of vegetation. The steppe is characterized with farms scattered in the grassland. the study site is the representative of the Eurasian temperate steppe[12] and the grasslands region of Inner Mongolia[13]. The dominate species in this zone are L. chinensis that is the typical vegetation of the grassland[14]. The grassland is native vegetation without grazing and additional treatments, including fertilization and grass seeding.

2.2 CH_4 uptake of temperate steppes

It is for these reasons that the Inner Mongolia steppes are often recognized as a sink for atmospheric CH_4[5]. However, Land-use conversions from grasslands to croplands and vice versa have occurred for pursuing higher economic benefits in the arid and semi-arid lands of Asia (ASAL) over the past decades. The agro-pastoral ecotone of Inner Mongolia in north China is included in the ASAL of Asia.

2.3The effects of CH_4 uptakes on land-use change

Land-use change are thought to be important factor for the magnitude of CH_4 uptake[15-17]. The changes in land use or intensification of land management directly affect CH_4 uptake and the atmospheric CH_4 budget[18-19]. The conversion of native grasslands into cultivated croplands has been shown to decrease the amount of atmospheric CH4 that is absorbed into the soil[6,11].CH_4 uptake in cropland (wheat field and fallow) which were poor in SOC was lower than in uncultivated short grass steppe sites which had greater amount of soil C[20-21]. Changes in land-use may have important consequences for the soil methanotroph and methanogen communities, the overall size of the soil CH_4 sink, and for the atmospheric concentrations[19,21].

2.4CH_4 uptake of Inner Mongolia steppes

How these changes have altered the CH_4 uptakes remains unknown. Moreover, few data is known regarding CH_4 uptakes specific to agro-pastoral ecotone, and few studies have been conducted on the effect of croplands age or soil properties on CH_4 uptakes in grasslands conversion to croplands.

2.4.1 CH_4 uptakes of conversion from native grasslands into cultivated croplands

Conversion from native grasslands into cultivated croplands has been shown to decrease the sink strength of soils for atmospheric CH_4[17-19,21-24]. Phillips et al.(2001) argued that differences in available C did not lead to obviously difference in CH_4 uptake. CH_4 oxidation may be limited by the flow of C and N to methanotrophs. Mineralizable C and other biochemical attributes of C-cycling (e.g. microbial biomass C, N) influenced CH_4 uptake. The kinetics of methane (CH_4) oxidation in soils is complex and their dependence on soil nitrogen (N) status remains an area of some controversy. The reason of land use change modified atmospheric CH_4 uptake rates appears to be modification in soil texture, bulk density, water status, microbial populations and, in some cases, N fertilization, and the intensification of mechanical soil perturbation by plowing and compaction by tractors or livestock[18]. However, the exact mechanisms influencing the biological or physico-chemical processes involved in methane uptake are not clear.

2.4.2 Influence factor of CH_4 uptakes in soil. Methane uptakes is influenced by several factors including temperature, precipitation, N input and soil properties (e.g., moisture, temperature, texture, pH and C/N ratio). Among these factors, soil properties are considered to be important drivers of the

magnitude of methane uptakes. However, Changes in land-use shift or intensification of land management directly affect soil properties, CH_4 uptakes and the atmospheric CH_4 budget[6-8]. The net CH_4 exchange between soils and the atmosphere is controlled by physical and chemical properties of soil that determine gas diffusivity, microbial activity and the balance between the processes of CH_4 production (methanogenesis) and oxidation (methanotrophy). Soil texture and soil water content influences gas diffusivity[9]. Wang et al. (2005) and Liu et al. (2007) found that CH_4 uptake rates and soil moisture were negatively correlated, while other soil properties were not discussed in these studies [1,10].

2.4.3 CH_4 uptake on the ages of conversion from grasslands to croplands. This trend has been primarily ascribed to tillage disturbance and N fertilization of soils[6]. However, In the past decades, many measurements of CH_4 fluxes have been taken in grasslands, documenting the grasslands as a major sources of CH_4[1,6,10]. However, the croplands of different ages from grasslands plowed has become another increasingly adopted agricultural system. The CH_4 fluxes from croplands with different age plowed have been rarely investigated, especially when simultaneously taking the adjacent grasslands as a reference. In the Inner Mongolia steppes, information of CH_4 uptakes on different time of the plowed grasslands conversion to croplands and these associated soil properties within the Inner Mongolia steppes is still scarce. The effects of the conversion of grasslands to croplands on CH_4 uptakes are uncertain. The determining factors that mediate the influence of land-use shift on CH_4 uptakes have not been elucidated.

3. The results of literature synthesis

In general, the net CH_4 uptake rate in croplands is determined by the final balance of CH_4 production, oxidation, and transport processes[11,25],which are associated with a variety of factors. Obviously, great changes would occur following conversion from grasslands to croplands, such as soil properties, nutrition cycling characteristics, and even over the all ecosystem function. Above changes would considerably alter the variation and amount of CH_4 uptakes.

4. Research emphasis on greenhouse gas emission reduction

Therefore, it is an important study in the agro-pastoral ecotone to investigate the effects of land-use shift on CH_4 uptakes. The objectives were to understand the impact of croplands age and soil properties on CH_4 uptakes following the conversion of grasslands to croplands. This study investigated CH_4 uptakes over a long period of time in an agro-pastoral ecotone in Inner Mongolia, China. Moreover, grasslands and adjacent croplands from grasslands plowed were compared and were derived from the same parent material under the same climate.

5. Results

This study was designed to address whether land-use shift affects CH_4 uptakes and what soil parameters are best for assessing CH_4 uptakes following the conversion of grasslands to croplands in the agro-grassland ecotone of Inner Mongolia. In addition, it should be focus of attention that the effects of physical and chemical soil properties on CH_4 uptakes were observed in this study in the future. Those results will support future modelling approaches that estimate CH_4 fluxes based on soil properties. In addition, further studies that couple CH_4 measurements with more analysis of soil methane bacteria over the course are needed. These further efforts will improve our understanding of land-use shift with different ages plowed and microbial impacts on the CH_4 uptake in the different land-use change.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China(41675140); the 2016 Inner Mongolia Youth Innovative Talent Training Program of Prairie Excellence Project. Wenzhu Yang and Yan Jiao conceived and designed the study. Jianghong Zhao and Jianhua Hou

performed the experiments in situ observation and measurement and analyzed the data. Wenzhu Yang and Yan Jiao wrote and edited the manuscript. All authors read and approved the final manuscript.

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