**643**

# Carbon balance analysis of a sown pasture in inland arid area, China

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**Abstract**

Grazing grasslands cover approximately 26% of the Earth's ice-free land surface, making them an important component in maintaining the global carbon balance. Recent research has shown significant carbon losses in soils under intensive pastures, particularly in developing countries where livestock farming is a dominant land use. This study aims to evaluate the net ecosystem carbon balance (NECB) of cultivated grassland grazing sheep pasture in the arid inland region of Northwest China. Based on life cycle analysis of carbon balance in grassland production systems, we hypothesis that grazing systems have a higher carbon sink capacity than hay harvesting systems because of the coupling between grassland and livestock. The sown pasture of wheat and alfalfa-fescue mixture rotationally grazed by sheep was the carbon sink, whilst the harvested pasture was the carbon source (four years). The carbon emissions per food equivalent unit (a food production units calculated based on protein and energy content) in the grazing pasture was 78.84% lower than that of the hay pasture. In grazing annual pasture and perennial pastures, the carbon emissions from livestock, processing and allocation of forage products accounted for 3.95%, 96.05% and 2.01%, 97.99% of the whole carbon emissions, respectively. The carbon emissions from sown pasture, where hay is harvested, mainly came from fertilization, irrigation and the processing and transportation of forage products. Therefore, strategies of carbon mitigation should focus on the greenhouse gas emissions of livestock production in grazing systems, and the processing and circulation of fertilization, irrigation inputs, and forage products in hay-harvesting pasture.

**Introduction**

Grazing grasslands, which account for 26% of the Earth's land surface and possess a substantial carbon (C) content in soils (Steinfeld et al., 2006), play a crucial role in the global carbon balance. The conversion of grasslands to cropland typically leads to a significant depletion of soil carbon (Davidson and Ackerman, 1993), while establishing pastures on previously cultivated land results in an increase in soil carbon (Post and Kwon, 2000). However, there is limited knowledge regarding the carbon balance of intensively cultivated grassland pastures and the impact of different patterns of grassland use and types on soil carbon. Previous studies have reported varying outcomes including increases, decreases, or no changes (Conant et al., 2001; Wang et al., 2011; Viglizzo et al., 2019; Lorenz et al., 2018). Therefore, this study aims to assess the net ecosystem carbon balance (NECB) of sheep grazing pasture within arid inland regions of Northwest China.

**Methods**

This study was conducted at Linze Grassland Agriculture Trial Station of Lanzhou University, Linze County, Gansu Province, China. Annual mean precipitation is 121~~.5~~ mm, and annual mean evaporation potential is 2390 mm. An integrated production system for sown pastures and sheep grazing has been established in the experimental area, consisting of two types of grassland: annual pasture (GA) and mixed perennial pasture （GP）. Sheep are rotated between these two types of grasslands, with grazing intensity controlled based on the height of the grass (GS). Grazing begins when the height reaches 20 cm and stops at 8 cm. The experiment covers a total area of 6 ha per grass type with three repetitions each. Additionally, a control group (HS) was set up in each type of grassland(HA, HP) using a 10 m x 10 m fence to harvest hay after maturity.

The carbon balance of a grassland agro-ecosystem is the cumulative sum of the carbon balances across its four production layers (pre-plant production system, PPP; plant production system, PP; animal production system, AP); post-biology production system, PBP) or three interfaces (Interface between herbage and site-interface A, IA; Interface between grassland and livestock-interface B, IB; Interface between grassland livestock system and social and economic management-interface C,IC). The carbon balance of a production layer or interface of a grassland system can be determined according to four parts. Carbon input (CI) refers to fertilizers, machinery, seeds, animal power, manure and other substances imported from outside the grassland system, $CO_2$ absorption and assimilation by photosynthesis, $CH_4$ and N fixed by microbial activities, and carbon and nitrogen accumulation by dust fall and soil and water conservation. Carbon emission (CE), human and livestock consumption of grass and livestock products, including food, energy, animal power, daily necessities, manure, is reduced to GHG within a certain period of time. Carbon fixation (CF), herbage, livestock, excrement, exists in a storable form in the grass industry system for a certain period of time. Carbon output (CO) refers to the output of grass and livestock products, seeds, animal power, manure. The carbon balance of the grassland system is CBGAE=CI+CF-CE-CO. If CBGAE > 0, that is, CI+CF > CE+CO, the grassland system is a carbon sink, and vice versa. The carbon balance of a production layer or an interface is calculated in the same way, and the sum of their initial carbon amount and carbon balance is the current carbon amount.

**Results**

The grazing system (GS) exhibits a positive carbon balance (> 0), indicating its role as a carbon sink. Carbon emissions primarily arise from the greenhouse gas release by sheep in AP, as well as the greenhouse gas emissions during the PPP's production process and livestock product output. Within the animal production layer, 43% of carbon is returned to the grassland through excrement, while 57% is discharged into the environment. The PBPcontributes to carbon emissions mainly through greenhouse gas emissions during its production process and from processing and outputting livestock products. Annual grazing grasslands (GA) demonstrate a higher carbon balance compared to perennial grasslands (GP).

The hay production system (HS) acts as a carbon source with a negative carbon balance. This can be attributed to higher levels of carbon emission in the plant production layer (PP) due to fertilization and irrigation practices. As there are no livestock involved, the animal production layer maintains a neutral carbon balance of zero. Carbon emissions within this system predominantly stem from greenhouse gas emissions during post-biological production processes and from processing and outputting forage products. Additionally, labor and mechanical input requirements are greater in hay production systems compared to grazing systems. Lastly, perennial mowing pasture (HA) exhibit higher carbon balances than annual pasture (HP).

**Discussion**

Grassland reclamation is the most violent human activity factor affecting soil carbon storage in grassland. The reclamation process will destroy the dense root layer, expose the deep organic carbon in the soil to the air, and accelerate the soil respiration process (Feng et al., 2019). When grassland is reclaimed for farmland, 30%-50% of the original soil carbon pool is lost, and most of this loss is caused by soil respiration emission (Genxu et al.,2002;

Rees et al., 2005). In this study, the emission of annual sown grassland was higher than that of perennial sown grassland, mainly because annual sown grassland needed to be tilled and sowing every year. In this process, the organic carbon in the deep soil was exposed to the air, which accelerated the soil respiration process.

Grazing has different degrees of influence on grassland plants, litter and soil (Li et al., 2024). These factors are not only important factors affecting grassland soil respiration (Kamran et al., 2023; Wang et al., 2023), but also affect the effects of water and heat factors on soil respiration to a certain extent. So far, there are many researches on the effects of grazing on soil respiration at home and abroad, but the results are not consistent. Some studies have shown that grazing can significantly reduce soil respiration intensity (Cao et al., 2004; Li et al., 2024), also found that the vegetation and soil conditions under fenced grazing were superior to those of grazing land, but the impact of grazing on soil respiration was not obvious (Zhao et al., 2016). In addition, studies have found that light grazing can promote soil respiration, while intensive grazing can reduce soil respiration rate (Koncz et al., 2015). It can be seen that grazing is still one of the uncertainties in estimating grassland carbon budget. In this study, the carbon balance of the grazing system is greater than that of the hay harvesting system, which is a comprehensive calculation based on the perspective of the whole ecosystem. The calculation result of the soil respiration part is that the soil respiration carbon emission of the grazing system is small, that is, the grazing reduces the soil respiration intensity and soil respiration emission.

According to the carbon input and output analysis methods of four production layers and three interfaces of grassland agro-ecosystem, the carbon balance of grazing system is the carbon sink, and the carbon balance of harvesting hay system is the carbon source. The contribution rates of the carbon balance of the four production layers to the carbon balance of the grazing system were 0.1% (pre-plant production system, PPP), 84.6% (plant production system, PP), -0.5% (animal production system, AP) and -17.0% (post-biology production system, PBP). The contribution rates to the carbon balance of mowing and harvesting hay system were 0.1% (PPP), 49.7% (PP), 0.0% (AP) and -51.1% (PBP). The carbon emissions of animal production layer and post-biological production layer in grazing system and harvesting hay system accounted for 3.95% (AP), 96.05% (PBP), 0% (AP) and 100% (PBP) of the system carbon emissions, respectively. The carbon balance of the three interfaces contributed 84.7% (BIA), 49.8% (BIB), -0.5% (BIC), 0.0%(BIA), -17.0%(BIB) and -51.1% (BIC) to the carbon balance of the grazing system and the harvesting hay system. The carbon emissions from mowing and harvesting hay, derived from fertilizers, irrigation inputs, and processing and circulation of forage products, are about three times that of grazing systems. The emission reduction of grazing system should pay attention to the animal production layer to reduce greenhouse gas emissions from the range-livestock interface. The hay production system should pay attention to the post-biological production layer, and reduce the carbon emission and carbon output in the process of product processing and circulation from the interface of grass and livestock systems-human activities.

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