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Identifying management strategies to improve sustainability and household income for herders on the desert steppe in Inner Mongolia, China

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ABSTRACT

Grasslands play important roles on all continents in ecosystem service and livestock production systems. With increasing human and livestock population, significant challenges are faced in providing safe and high quality animal and herbage products from grasslands in China. The family ranch is the basic management unit and production system in Inner Mongolia, north China. Animal populations are increasing, but the income of herders and grassland condition are not improving. There is a need for new management strategies to guide the future development of animal husbandry. Based on the results of demonstration experiments and surveys in Siziwang Banner, the *StageONE* Model developed for Australian Centre for International Agricultural Research (ACIAR) project "*Sustainable Livestock Grazing Systems on Chinese Temperate Grasslands*" was used to simulate changes in management strategies in a typical whole farm system, in order to identify feasible, sustainable and profitable farm management strategies. A new management strategy, including lower stocking rates and increased use of feed supplement in winter and spring, was adopted in a small number of farms and compared with the typical farm using the *StageONE* model. The results show that the total actual energy intake of sheep in the new strategy is higher than under traditional management, and the net energy surplus is −0.36 MJ/sheep unit/d, which is lower than under traditional management. The new strategy, in which stocking rates are reduced by 14.1%, also reduced methane emissions by 34.14% and increased net income by 15.85%. The simulation results suggest new ways for herders, companies and government to improve grassland management while increasing herders' net incomes.

1. Introduction

Grasslands, which occupy about 30% of the world's ice-free land surface and 70% of its agricultural lands (Reynolds and Frame, 2005; WRI, 2000; White et al., 2000) have important values for ecosystem services and livestock production on all continents (Suttie et al., 2005; Millennium Ecosystem Assessment, 2005; Havstad et al., 2007). With increasing human population and livestock numbers, the capacity of existing grassland resources to support resilient and high quality animal and herbage production is under threat (Estell et al., 2012). These challenges are also evident in China. There are approximately 400 million hectares of grassland in China, covering 41% of the total land area, which is two times larger than the cropland area and three times larger than the forest area (Ren, 1995). The northern grasslands of China are important for both animal production and ecological protection. Production systems in this area are characterized by extensive grazing with low inputs and large numbers of livestock. In Inner Mongolia Autonomous Region (IMAR), population growth and increased demand for animal products in the rest of China have driven an increase in animal numbers of 127% from 1990 to 2011(Inner Mongolia Autonomous Region Statistics Bureau, 1991–2012) (Fig. 1). Over this same period, there was a decreasing trend in natural grassland production in IMAR due to grassland degradation and climate change. Overgrazing has been a main factor driving grassland degradation. The ranchers who are faced with a variety of economic constraints and incentives may find

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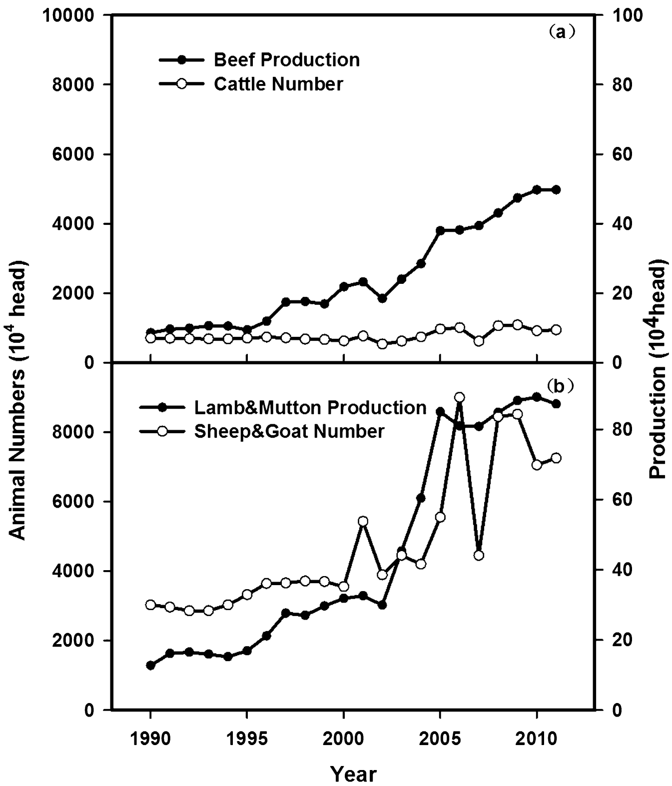

Fig. 1. Total cattle, sheep and goat numbers and meat production in Inner Mongolia Autonomous Region, 1990–2011. (a) Total beef production and cattle numbers; (b) total lamb and mutton production, and sheep and goat numbers. (Data source: Inner Mongolia Autonomous Region Statistics Yearbook, 1991–2012).

that it is in their personal best interest to overstock (Pope and McBryde, 1984). In China, with expenses increasing, income increments slow down, the ability to anticipate income is poor and lack of willingness to pay for ecological services leads to overgrazing (Ning and He, 2006). The design of the institution of property right is confused and institution is lagging which makes utilization and protection of grassland out-of-order, and tempts the herders to overstock the grassland which leads to overgrazing over time (Zhao et al., 2005).The traditional management strategy, based on extensive grazing and limited supplementation in winter, is not able to satisfy livestock energy demand. Since 2002, central and local governments have adopted many policies and measures to promote grassland recovery and conservation, and promote economic development in pastoral regions (e.g., relocation of households from degraded areas, forage reseeding, grazing bans and fencing). However, these measures are all expensive and unsustainable (Han et al., 2013).

Pasture is the cheapest source of feed systems (Doyle et al., 2004; Fulkerson and Doyle, 2001), pasture utilization needs to be maximized, and the benefits of adopting either of these strategies will depend on the effect on this variable. Some research shows that increasing stocking rate can improve pasture utilization and pasture quality in farm system (Baker and Leaver, 1986; Fales et al., 1995; Holmes and Parker, 1992; Macdonald et al., 2008; Stockdale and King, 1980), but most research shows that continuous higher stocking rate leads to reduction of the net income of herders and this impacts the development of all animal husbandry practices (Eigenraam et al., 2000; Jia and Wang, 1994; Michalk et al., 2003; Rittenhouse and Roath, 2002; Tilman and Downing, 1994; Tilman et al., 1996). It is difficult to find the effect of stocking rate on animal production and economic benefits (McCollum et al., 1999), but values for the vegetation and soil are easier to find based on the condition of the grassland. Higher stocking rate normally results in lower pasture allowances for each animal, substitution effects could be reduced, and resulting in a more efficient use of supplements at the system level (Kellaway and Harrington, 2004; Wales et al., 1999). Profitability is closely related to stocking rate (Cayley et al., 1999). As stocking rate increases, production per animal will decrease as competition for resources and production costs become limiting but production per hectare will exhibit a quadratic response initially increasing before declining. In general, producers choose a stocking rate where total revenue is above total costs (McGuigan et al., 2002). High stocking rates on pasture-based systems can reduce animal performance (Dillon et al., 1995; Holmes and Parker, 1992; King and Stockdale, 1980; Macdonald et al., 2008). Compared with moderate stocking rate, under high stocking rates animal condition decreases (Holechek et al., 2010). Optimal stocking rates on rangeland depend on the planning horizon and the interest rate used to discount the value of future benefits from rangeland use (Pope and McBryde, 1984). Managing to minimize economic losses and degradation in semi-arid rangelands with light and variable stocking strategies is essential in extensive Australia rangeland (O'Reagain, *et al*., 2003). When the stocking rate exceeds optimal stocking rates, average daily weight gain of grazing animals declines (Ackerman et al., 2001) and economic benefit will also decline (Shoop and McIlvain, 1971; Whitson et al., 1982). Since the early 1980s, the family ranch has been the basic management unit and production system in northern China (Ding, 2008). The management strategies adopted in family ranches have direct implications not only for the utilization and protection of grassland resources, but also for GHG emissions, especially methane from ruminant livestock enteric fermentation and excrement. Methane (CH_4) is the second most important greenhouse gas, contributing an estimated 18% of the overall global warming potential (Murray et al., 2001; Wang et al., 2014). Between 1994 and 2005, emissions from livestock enteric fermentation (37% of China's total emissions) have been the largest agricultural source of GHG emissions in China (NCCC, 2004, 2012). In the desert grazing system, between 2% and 12% of gross energy intake can be lost due to methanogen activity of ruminants (Johnson and Johnson, 1995). Research points to several potential management measures to control and mitigate ruminant methane emissions, such as improving diet quality, increasing feed additives, and improved production efficiency (Boadi et al., 2004; Kebreab et al., 2006; Ogle et al., 2010; Ominski and Wittenberg, 2006). For effective and sustainable adoption, these measures need to be integrated into farm management strategies that improve grassland condition while increasing herders' incomes (Pannell et al., 2006).

This study uses model-based simulations of energy balance in the typical farm system to identify sustainable strategies applicable to the typical family ranch in Siziwang Banner, IMAR, in order to achieve 'triple-win' outcomes for herders' incomes, grassland conservation and mitigation of GHG emissions.

2. Methods

2.1. Experimental site description

The research site is located in Siziwang Banner, IMAR (Fig. 2). The landscape is undulating, and land type includes cropland and grassland in local. Grassland degradation, due to overgrazing and drought, is widespread and severe (Han et al., 2011). Elevation averages 1400 m. The climate is characterized as continental, windy in spring, with low precipitation in summer, and dry and cold throughout winter. The annual average temperature, precipitation and evaporation are 4.1 °C, 305 mm and 2213 mm, respectively (Fig. 3). The frost-free period is 175 d. The main vegetation type is desert steppe. The soil is Kastanozem (FAO, 2006) with a sandy loam texture. The dominant plant species of the study area are short flower