Agriculture, Ecosystems and Environment 186 (2014) 115–123

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

# Restoring the degraded grassland and improving sustainability of grassland ecosystem through chicken farming: A case study in northern China

Hong Xu[a], Hua Su[a], Benying Su[b], Xingguo Han[a,c], Dilip K. Biswas[d], Yonggeng Li[a,*]

[a] State Key Laboratory of Vegetation and Environmental Change Institute of Botany, Chinese Academy of Sciences, Beijing 100093, PR China
[b] Key Laboratory of Crop Ecophysiology and Farming Systems in Southwest China, Ministry of PR China, Sichuan Agricultural University, Chengdu 611130, Sichuan, PR China
[c] State Key Lab Forest & Soil Ecol, Institute of Applied Ecology, the Chinese Academy of Sciences, Shenyang, Liaoning, PR China
[d] Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, ON, Canada K1A0C6

ARTICLE INFO

*Article history:*
Received 9 June 2013
Received in revised form 20 January 2014
Accepted 1 February 2014
Available online 23 February 2014

*Keywords:*
Chicken farming
Grassland restoration
Integrative ecosystem management
Nutrient addition
Sustainability development

ABSTRACT

Long-term irrational land uses have fatigued the fragile grasslands globally, causing severe environmental problems and socio-economic losses. This paper addresses the feasibility of a new land use of chicken farming (CF) from natural, economic and social perspectives for devising sustainable development in a semi-arid grassland in northern China. The results of a 4-year controlled field experiment showed that CF could amend the infertile soils through feces inputs as indicated by the improvements in soil properties. Although there were some damage to grass growth in the first year of the experiment, vegetation coverage and aboveground biomass increased greatly in the following years, particularly in the third and fourth years. A quarter of feedstuff could be saved by chickens farmed in grassland compared with cage-raised chickens, accompanied by biological control of pest outbreaks. The 4-year practice at large scales by local household suggested that CF could be a more profitable enterprise compared to the conventional land use of ruminate grazing. Besides, CF could diversify livelihoods, which will lighten the reliance on traditional livestock grazing and thus help improve local social-ecological development. It was concluded that CF could be an integrative ecosystem management to rehabilitate the degraded grassland ecosystems toward a sustainable way. Finally, we highlighted an essential integration of bottom-up mechanism among local households with top-down incentives created by governments for sustainable development of chicken farming in the degraded grassland regions.



## 1. Introduction

Long-term irrational land uses, such as overgrazing and overcropping, have fatigued the fragile grassland ecosystems globally (MEA, 2005). The arid and semi-arid grasslands in northern China, covering an area of 287 million ha in Eurasia steppe, are not only an important foundation of livestock and forage production, but provide multiple irreplaceable ecosystem services (e.g., carbon sequestration, wildlife habitat, and *in situ* conservation of biodiversity, etc.) (Dong et al., 2012; Li et al., 2008; Ni, 2002). However, changes which have developed since the semi-private property rights arrangement known as the Household Production Responsibility System started in 1980s, have led to soaring stocking rates and overcropping (Han et al., 2008; Li et al., 2007; Li and Huntsinger, 2011; Liu and Diamond, 2005). Such intensive uses, alone or acting in concert with climatic variations, resulted in severe land degradation, which has triggered a cascade of environmental problems (e.g., wind erosion, sandstorms, land desertification) and dramatic socio-economic losses (Jiang et al., 2006; Li et al., 2007, 2008, 2012; Unkovich and Nan, 2008; Wang et al., 2002).

A series of costly top-down restoration measures and policies have been launched in the past decades, including Grain-to-Green Program, Ecological Migration Project, and grazing exclusion measure, etc., which have improved the ecological environments notably (Liu and Diamond, 2005; Normile, 2007; Wang et al., 2011). Nevertheless, grassland restoration is still a critical challenge facing agricultural production, rural development and environmental improvement (China State Council, 2012; Nan, 2005). The traditional ruminate husbandry, which is strongly relied on by local residents, has been seriously distressed by current low grass

* Corresponding author. Tel.: +86 1062836596.
*E-mail address:* liyonggeng@ibcas.ac.cn (Y. Li).

http://dx.doi.org/10.1016/j.agee.2014.02.001
0167-8809/

productivity (no more than 50% of that in the 1950s) together with frequent extreme climate events (i.e. drought, pest outbreaks and snowstorms) (Qi et al., 2012). Soil fertility including levels of soil organic matter is inescapably being depleted through long-term nutrients remove in harvested materials and losses through erosion, leaching or gaseous emissions (Chen, 1987; Feng et al., 2002; de Haan et al., 1997; Dong and Zhang, 2005; Pei et al., 2008). Organic or inorganic fertilization can restore the productivity of degraded grasslands and has been applied as a most common management in the managed grazing ecosystems (Conant et al., 2001; Ryals and Silver, 2012). A number of field experiments have proven that nitrogen addition increases net primary productivity and can advance the restoration of the degenerated grassland in northern China (Pan et al., 2005; Bai et al., 2010). However, low income households cannot afford to fertilize these marginal drylands, resulting in gradual degradation of soil fertility.

Our research addresses the question, "Can the natural grasslands be more productive in forage provision and animal production in a sustainable way?" In some European countries, pastured poultry has been widely integrated into other farm enterprises (Berton and Mudd, 2000), which is proven as a profitable livestock production system and can help keep more family farmers on their lands (Glatz et al., 2005; Sossidou et al., 2011). Moreover, chickens offer other potential benefits through controlling pests and distributing their manure to grassland ecosystems (Sossidou et al., 2011). In China, with the enhanced purchasing power and the increasing concerns over food safety, the domestic consumption of free-range chickens is increasing. This gives a great opportunity for the development of chicken farming in the vast grasslands with rich natural resources (e.g., seeds, herbs, and insects) to be an alternative livelihood for local residents. As ecological and social issues are fundamentally interwoven particularly in the drylands (Reynolds et al., 2007), livelihood diversification may contribute to the sustainable development in grasslands (MEA, 2005; Adeel and Safriel, 2008). Thus, we hypothesized that integration of free-range chicken production into the traditional husbandry in degraded grasslands may help improve the natural environment and enhance social-economic development.

Since 2009, the Chinese Academy of Sciences launched one demonstration project in Hunshandak sandy grassland in northern China to test whether chicken farming can restore the social-ecological development in the degraded grasslands. This paper documents the following results of chicken farming in grasslands: (1) impacts on soil fertility and grass growth, (2) feedstuff savings compared to cage-raised chicken, (3) potential of pest control, and (4) feasibility as an alternative livelihood practiced by local households. Our case study will provide helpful information for proper policy making and a scientific strategy for sustainable development of grasslands.

## 2. Materials and methods

### 2.1. Site description

The case study was carried out at a demonstration base of the Hunshandak Sandland Ecosystem Research Station of Institute of Botany, Chinese Academy of Sciences (42° 54′ 15.2″N, 116° 00′ 57.63″E, 1,300 m elevation a.s.l.) at the central Xilingol League, Inner Mongolia Autonomous Region, which is adjacent to an agro-pastoral ecotone in northern China (Fig. 1). This research base is located in a typical village Bayinhushu with 84 families, 295 people and 8400 ha natural rangelands. The livelihood of the villagers totally depends on large ruminate animal (i.e., cow, cattle and sheep) grazing to produce milk, meat, wool. This village has witnessed the ecological disasters of land degradation as happened in the whole grassland regions in northern China before 2000, and thereafter the past decade of top-down restoration projects including reforestation, aerial seeding, livestock exclusion, and the introduction of cows, etc., trying to rehabilitate degraded grasslands (Jiang et al., 2006; Normile, 2007). Although the ecological environment has been greatly improved, 80% of the rangelands are still under different levels of degradation.

Climatically, the research site belongs to the continental zone, characterized by short cool summer with average temperature of 18.7 °C and long harsh winter with extremely low temperatures below −35 °C. Mean annual precipitation is about 314 mm (30-year average), 60–80% of which falls during the growing season from May to August. Mostly north-westerly winds have an annual average speed of 3.6 m $s^{-1}$. Different from European pastures, grasslands in northern China with such continental climate may be only feasible to raise chickens in a free-range way during the short cool summer.

### 2.2. Experiment design and measurements

#### 2.2.1. Impacts of chicken farming on biophysical variables of grasslands

A field experiment was established in a degraded sandy grassland in June 2009 and continued for four growing seasons to September 2012. The grassland is dominated by rhizomatous *Leymus chinensis* with 19 plant species. The 5-year average aboveground net primary productivity was around 100 g $m^{-2}$ $yr^{-1}$ (communications with the landowner) (grass growth similar as Fig. S1B). The soil is composed of chestnut and aeolian sandy soil with sand, silt and clay in the surface soil (0–20 cm) being 91.53%, 6.12% and 2.35%, respectively. No artificial additions of organic or inorganic fertilizers were applied prior to the experiment. Average total N, organic C and pH value in the surface soil were 0.34 g $kg^{-1}$, 4.18 g $kg^{-1}$ and 7.41, respectively.

Treatments consisted of non-grazed control and chicken farming treatment (CF). Plots (10 m × 40 m) were surrounded with plastic netting and separated from each other by 2 m buffers. They were arranged in four randomized compete blocks. The control plots were free from livestock grazing and vegetation inside grew naturally. In mid-June each year from 2009 to 2012, twenty 6-week-old chicks (a slow-growing local chicken variety named as Huabei Chaiji) were put into each CF plot to set a stocking rate of 500 chicken $ha^{-1}$. Birds were allowed to range freely inside the CF plots during daytime and locked in a chicken house at night. They were daily fed with particulate feedstuff (80 g per chicken, 1600 g for 20 chickens) in a tub and adequate water in another tub at 06:00 a.m. (Beijing time). Tubes were put beside the house in each CF plot. The feedstuff is a mixture of corn and dregs of beans at the ratio of 4:1 with total sugar content of 61.8% and crude protein content of 16.1%. Birds were harvested by the end of September. Afterwards, all the plots were mowed to 5 cm above the surface.

*2.2.1.1. Soil sampling and measurements.* In early August of each year, surface soil (20 cm depth) was sampled using a soil corer (5 cm in diameter) respectively, at zone 2, 10, 18, 26, and 34 m away from the chicken house in each CF plot. Three soil cores were collected and mixed *in situ* into one composite sample at each sampling zone. In each control plot, five soil cores were randomly collected and mixed *in situ* into one composite sample. All samples were passed through a 2-mm sieve to remove roots, and then air-dried. Subsamples were sieved through 1.0-mm and 0.25-mm sieves. Soil organic matter was determined using the wet combustion method. Soil mineral nitrogen ($NH_4^+$–N and $NO_3^-$–N) was extracted with 2 M KCl (soil to extractant ratio = 1:10, w/v) (Mulvaney, 1996), and then determined using a flow injection autoanalyzer (FIAstar 5000 Analyser; Foss Tecator, Hillerød, Denmark). Analysis of