Agricultural Systems 150 (2017) 67–77

Contents lists available at ScienceDirect

Agricultural Systems

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

Is crop biomass and soil carbon storage sustainable with long-term application of full plastic film mulching under future climate change?

Feng Zhang [a,*], Wenjuan Zhang [b,c], Ming Li [a], Yuan Zhang [d], Fengmin Li [a], Changbin Li [e]

[a] Institute of Arid Agroecology, School of Life Sciences, State Key Laboratory of Grassland Agro-ecosystems, Lanzhou University, Lanzhou, Gansu 730000, China
[b] Qinghai Grassland Management Administration, Xining, Qinghai 810000, China
[c] School of Pastoral Agriculture Science and Technology, State Key Laboratory of Grassland Agro-ecosystems, Lanzhou University, Lanzhou, Gansu 730000, China
[d] Key Laboratory of Geographical Information Science, Ministry of Education, East China Normal University, Shanghai 200241, China
[e] Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, Lanzhou 730000, China

ARTICLE INFO

Article history:
Received 10 December 2015
Received in revised form 21 October 2016
Accepted 24 October 2016
Available online xxxx

Keywords:
Carbon
Biomass
Plastic film mulching
Loess plateau
DNDC

ABSTRACT

The ridge–furrow with full plastic film mulching system (PM) is one of the most popular and widely applied field management techniques in dryland areas of China. There is concern for soil carbon storage and crop productivity dynamics under the long-term application of this management, specifically given the background of global climate change. However, the long term effects of this management practice are still poorly understood. More evaluation is required. A process-based biogeochemical model revised through four years of field experiments and a model drive by RCP (Representative Concentration Pathway) projection was applied to explore how soil carbon storage and maize productivity would change under future climate change projections. The field experiment showed that biomass was significantly higher in the PM than cultivation without mulching (CK), and their four-year average biomass values were 4996 ± 967 and 2850 ± 817 kg C ha^{-1}, respectively. Meanwhile, the four-year average soil organic carbon (SOC) storage was 5.93 g C kg^{-1} soil, 5.95 g C kg^{-1} soil and 5.40 g C kg^{-1} soil for (CK) and 5.83 g C kg^{-1} soil, 5.78 g C kg^{-1} soil and 5.58 g C kg^{-1} soil for PM at depths of 0–10, 10–20 and 20–30 cm, respectively. SOC did not significantly differ between the two treatments within the four years of the experiment. The model simulation with various rainfall and temperature change scenarios indicated that SOC (0–30 cm) and biomass were more affected by climate change in CK compared to PM. During years 2016–2100, SOC and maize biomass constantly increased under PM and CK for the RCP 4.5 and RCP 8.5 scenarios, and biomass was higher for PM than CK. However, under the highest carbon dioxide emission scenario of RCP 8.5, the improved biomass and SOC in PM decreased when temperature increased by more than 2.85 °C after year 2060. The modeling results showed that the PM cultivation system maintained high productivity and increasing trends of SOC under the high and medium greenhouse gas emission scenarios, derived from climate change projections for before the year 2060. The PM is currently an effective way to increase productivity and is a possible measure for dryland agriculture to adapt to near future climate change.

1. Introduction

Drylands cover 41% of the earth's land surface and are home to more than 38% of the total global population of 6.5 billion (Reynolds et al., 2007). Dryland ecosystems are generally considered to be among the most sensitive and responsive to human-induced global changes (Reynolds et al., 2007). The Loess Plateau in China is typical dryland—with rainfall of 300–600 mm—approximately 64 million hectares in area and supports a population of about 100 million people (Y. Chen et al. 2015). The wide impact of a thousand years of agricultural utilization, limited rainfall and high evaporation constrain agricultural development in the Loess Plateau. Many agricultural management strategies have been tested to improve rainwater use efficiency in semi-arid regions over recent decades (Zhao et al., 2014). Integrated ridge–furrow configuration with plastic mulch (PM) technology is one of the most successful measures and has been effectively used to improve crop production throughout the world (Gan et al., 2013; Kasirajan and Ngouajio, 2012; Lamont, 2005; Liu et al., 2009; Zhou et al., 2009). For the most efficient water use, PM has recently gained huge popularity in the Loess Plateau (C.A. Liu et al. 2014; Ye and Liu, 2012; Zhao et al., 2014; Zhou et al., 2009). The PM management markedly increased crop production compared with conventional management. In the last decade, an enormous amount of cropland has been changed to PM, and the area rapidly expanded to 7 million hectares by 2012 in western China (Fan and Xie, 2012; Liu et al., 2009; Mo et al., 2013; Zhou et al., 2009). Under PM management, the soil surface is fully covered with polyethylene plastic, which greatly reduces

* Corresponding author.
E-mail address: zhangfeng04@gmail.com (F. Zhang).

http://dx.doi.org/10.1016/j.agsy.2016.10.011
0308-521X/

evaporation from soil and changes soil moisture and temperature over the entire growth period (C.A. Liu et al. 2014). Furthermore, biomass and soil respiration are significantly increased (Y. Chen et al. 2015; Li et al., 2004). With higher production and soil carbon (C) turnover rate, there are increasing concerns for sustainability of the PM system (Gan et al., 2013; Zhou et al., 2012). Focusing on the 'slow variable' is critical to study the sustainability of a human–environment coupled dryland system (Carpenter and Turner, 2000; Reynolds et al., 2011). The soil organic carbon (SOC) content is typically the slow variable, which is the result of the long-term net balance between loss and accumulation of organic C in soil, and SOC level is one of major indicators of sustainability of an agricultural ecosystem.

The better soil hydrothermal environment in plastic-mulched croplands can significantly change the soil C balance. Some studies have found no significant differences in SOC between PM and no-mulch fields (E.X. Liu et al. 2014; Luo et al., 2015a, 2015b). However, climate change could bring more uncertainty to soil C storage under PM management. Therefore, short-term field experiments are insufficient to assess the long-term variability of SOC under PM. Model assessment is essential to evaluate sustainability of PM with a long-term perspective. So far, however, there has been no discussion of the impact of future climate change on the PM system.

A four-year field experiment was implemented to study the SOC and maize biomass change in a PM field in the short period and a revised process-based DeNitrification-DeComposition (DNDC) model was applied to evaluate the sustainability of biomass and SOC under PM in the long-term for future climate change projections.

2. Method

2.1. Field experiment design

2.1.1. Site description

The field experiment was conducted during 2011–2014 in a 40-year-old manmade terrace (36.03°N, 104.42°E, 2318 m above sea level), located in the northern mountain region of Yuzhong County, Gansu Province, China (Fig. 1b). The annual mean air temperature, annual accumulated temperature above 0 °C, precipitation and wind speed in the closest national metrological station (i.e. Yuzhong) over the past 30 years were 6.75 °C, 2310 °C, 371 mm and 1.9 m s^{-1}, respectively. Groundwater is unavailable and rainfall is the only water source for crop growth. The soil contained 37% clay (<0.002 mm), 59% silt (0.002–0.05 mm) and 4% sand (0.05–2.0 mm).

2.1.2. Experimental design

The field experiment included two treatments and a randomized complete block design was used: (1) ridge–furrow system without mulching (CK); (2) PM; and each treatment was replicated three times using 10 m × 10 m plots.

2.1.3. Agronomic practices

The land was prepared according to local regular maize management requirements. The roto cultivator tillage was applied and fertilizer was broadcast to the plot. The width of the ridges was 0.55 m, and triangular furrows between two ridges were 0.55 m wide and 0.10 m deep (Fig. 1a, c). The plant spacing in each row was 40 cm, and the seeding density was 47,500 plants ha^{-1}. For PM treatment, transparent plastic film of 0.0075 mm thickness and 1.1 m width was applied on the ridge and furrow surface (fully covering) with the edges held tightly under the soil at the beginning of the season. The plastic film continually covered the soil surface throughout the growing season. After germination, holes were made in the film at the place of plant emergence, with one maize plant per hole.

2.1.4. Soil sampling

Soil of 0–30 cm depth was sampled at 10-cm intervals with a soil drill (metal cylinder: diameter of 5 cm, length of 20 cm and total length of the sampler 1.3 m) at sowing and end of harvesting. 5 samples were collected in each replication plot in both ridges and furrows. The ground

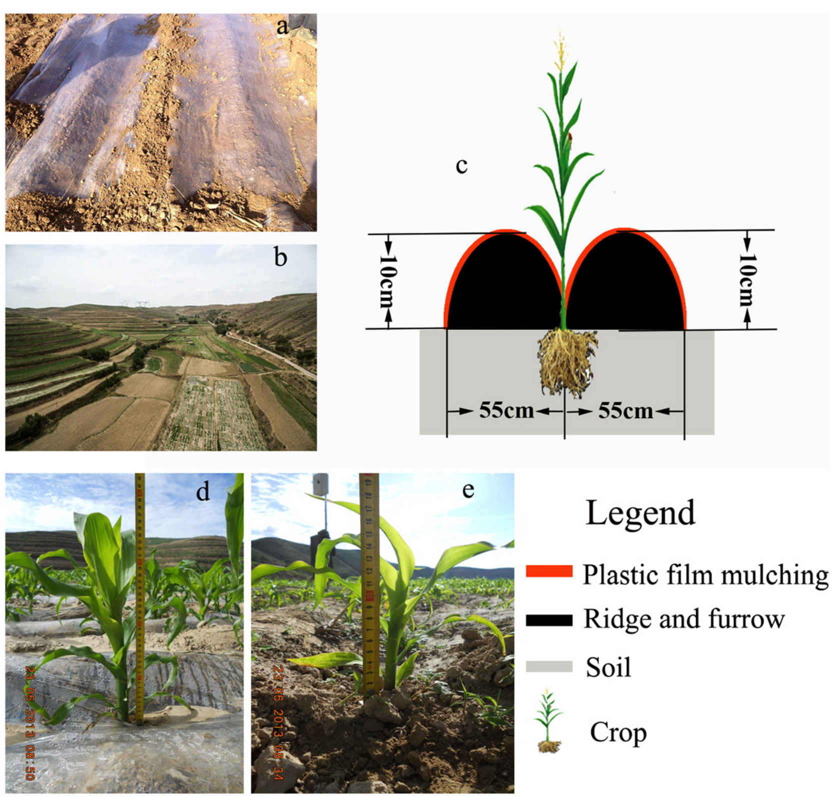

Fig. 1. Experiment field. a. Ridge-furrow with full plastic film mulching configuration. b. Experiment field panorama; c. ridge-furrow with full plastic film diagram; d, e: the filed with full plastic film mulching and without mulching at same day.