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Response of Artificial Grassland Carbon Stock to Management in Mountain Region of Southern Ningxia, China

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Abstract: Grassland is a major carbon sink in the terrestrial ecosystem. The dynamics of grassland carbon stock profoundly influence the global carbon cycle. In the published literatures so far, however, there are limited studies on the long-term dynamics and influential factors of grassland carbon stock, including soil organic carbon. In this study, spatial-temporal substitution method was applied to explore the characteristics of *Medicago sativa L.* (alfalfa) grassland biomass carbon and soil organic carbon density (SOCD) in a loess hilly region with different growing years and management patterns. The results demonstrated that alfalfa was the mono-dominant community during the cutting period (viz. 0–10 year). Community succession began after the abandonment of alfalfa grassland and then the important value of alfalfa in the community declined. The artificial alfalfa community abandoned for 30 years was replaced by the *S. bungeana* community. Accordingly, the biomass carbon density of the clipped alfalfa showed a significant increase over the time during 0–10 year. During 0–30 year, the SOCD from 0–100 cm of the soil layer of all 5 management patterns increased over time with a range between 5.300 ± 0.981 kg/m^2 and 12.578 ± 0.863 kg/m^2. The sloping croplands had the lowest SOCD at 5.300 ± 0.981 kg/m^2 which was quite different from the abandoned grasslands growing for 30 years which exhibited the highest SOCD with 12.578 ± 0.863 kg/m^2. The ecosystem carbon density of the grassland clipped for 2 years increased 0.1 kg/m^2 compared with the sloping cropland, while that of the grassland clipped for 10 years substantially increased to 10.30 ± 1.26 kg/m^2. Moreover, the ecosystem carbon density for abandoned grassland became 12.62 ± 0.50 kg/m^2 at 30 years. The carbon density of the grassland undisturbed for 10 years was similar to that of the sloping cropland and the grassland clipped for 2 years. Different management patterns imposed great different effects on the accumulation of biomass carbon on artificial grasslands, whereas the ecosystem carbon density of the grassland showed a slight increase from the clipping to abandonment of grassland in general.

Keywords: artificial *Medicago sativa L.* (alfalfa) grassland; clipped grassland; abandoned grassland; carbon sink; carbon density; mountain region; southern Ningxia

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1 Introduction

The grassland ecosystem is a significant kind of carbon sink due to its large area and diverse types (Jackson *et al*., 2002). The total carbon stock of global grassland accounts for approximately 12.7% (266.3 Pg) to 31% (761 Pg) of the whole terrestrial ecosystem (Whittaker and Niering, 1975; Prentice, 1993). Hence, the grassland ecosystem plays a key role in the global carbon cycle (Canadell *et al*., 2000).

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Grassland soils in mountain regions are major carbon sink in the terrestrial ecosystem (Ni, 2002; Chen and Shang, 2011). Soil organic carbon in these regions decomposes slowly because of the low temperature. According to Ajtay *et al*. (1978), 89.4% of the grassland carbon stock is in the grassland soils and the carbon stock in the grassland soil comprises 15.5% of the soil organic carbon worldwide. Ni (2002) claimed that the grassland ecosystem carbon sink in China was 44.09 Pg. The carbon sinks of grasslands and meadows in mountain and temperate regions account for 40.1%. The 95% of the carbon sinks of grasslands and meadows in the mountain and temperate regions in China are found in soils in the form of organic carbon, which is 13.5 times to that of vegetation stratum and similar to the distribution features of grassland carbon stocks worldwide. These carbon stocks account for about 55.6% of the total soil carbon stocks in China. Therefore, the dynamics of the carbon stocks of the grasslands and meadows in the mountain and temperate regions in China significantly influence the global carbon cycle. Studies on the dynamics and influencing factors of these carbon stocks can help to understand the global carbon budge and would be benefit for carbon cycle management (Yao and Gao 2006; Zhang, 2010).

In several cases, the carbon cycle of the grassland ecosystem in mountain regions changes because of management patterns. Recently, the construction of grassland in the mountain regions of China has been significantly influenced by artificial pasture, which profoundly influences the grasslands area and possibly changes the regional grassland carbon cycle. For example, the ecological restoration projects such as Grain for Green program strongly contribute to the restoration of the grassland carbon pool (Yu *et al*., 2012). When the farmland is converted to grassland, soil organic carbon is permanently stored and accumulated at a rate of 0.54 Mg/ha·yr (Conant *et al*., 2001); conversely, after natural grassland is reclaimed to farmland, the loss rate of the soil organic carbon at 30 cm of the surface soil reaches over 20% because of farming and erosion (Liu *et al*., 2004; Yan *et al*., 2008; Huang *et al*., 2010).

The Loess Plateau is an important region for Grain for Green program, and the artificial *Medicago sativa L.* (alfalfa) grasslands have been experienced clipped and then abandonment during the program. Thus, there are three kinds of grasslands including: 1) artificial alfalfa grasslands with clipping treatment, 2) abandoned alfalfa grasslands which is no longer being clipped, and 3) natural grassland. Clipping treatment can influence the composition of the grassland ecosystem (Bao *et al*., 2004), affecting the carbon cycle by reducing the net carbon stocks of the ecosystem (Zhang *et al*., 2005). After several years, the artificial alfalfa grasslands were gradually abandoned because of the implementation of Grain for Green program. Thus, the succession of artificial alfalfa grasslands was initiated, and the species composition will change over time and become subsequently different from that of the grassland that undergoes continuous clipping or the natural grassland (Li *et al*., 2006). Therefore, there may be a substantial change in soil organic carbon content of the alfalfa grassland with clipping treatment and abandoned alfalfa grassland over time. However, the long-term organic carbon dynamics of grassland under a changed management have been seldom reported.

In this study, the artificial alfalfa grassland under different management patterns in mountainous region in the southern Ningxia on the Loess Plateau was investigated to explore whether the carbon sink has been turned into a carbon source from the early-stage clipping (first 10 years) to the later abandonment of the grassland. In this way, the study revealed the transformation of the grassland utilization forms and dynamics of the ecosystem carbon stock in its long-term evolution.

2 Materials and Methods

2.1 Investigated region

The investigated region is located in the Wuchuan Village, Wenbao Town of Longde County in the southern Hui Autonomous Region of Ningxia. The study region has a typical temperate continental climate. The altitude is from 2000 m to 2100 m. The mean annual precipitation is 442.7 mm. The seasonal distribution of the precipitation is very uneven, about 60% of the annual precipitation occurs from July to September. Hence, the annual variation coefficient of the precipitation is large. The months with concentrated rainfall often have rainstorms. The mean annual evaporation capacity is 1360.0 mm, which is more than thrice to the precipitation. The annual average temperature is 7.5℃, and the accumulated temperature ≥ 10℃ is between 2500℃ and 2800℃. The frost-free period is 147 d to 168 d. The annual average wind speed is 2.7 m/s.

The soil type in the investigated region is loess soil, which is young soil generated from the loess parent material and shows alkalescency. The soil layer is thick and loose. The grassland in this region has various herbaceous plants such as *Stipa bungeana*, *Cirsium setosum*, *Ixeris chinensis*, *Heteropappus altaicus*, *Plantago asiatica L.*, and *Artemisia sacrorum Ledeb*.

2.2 Methods

2.2.1 Selection of sampling plots

In this study, some local elders have been interviewed to identify the artificial alfalfa grasslands with different growing years, which underwent clipping in the early period of planting using the spatial-temporal substitution method. Elevation, slope, aspect, position, and soil conditions were considered. Twelve suitable plots were selected to ensure efficient comparability. Three plots were set in artificial alfalfa grassland clipped for 2 years or 10 years. Two plots were set in the abandoned alfalfa grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years. The controls were set up in three sloping croplands and one plot of undisturbed artificial grassland restored from farmland for 10 years. The alfalfa grasslands for the first decade after planting were cut once each year from July to September. The main information of the selected plots can be found in Table 1.

2.2.2 Sample collection and pretreatment

(1) Vegetation sample collection. The sample collection was conducted in September 20–26, 2011. Three repeated smaller subplot (1 m × 1 m) were set in each plot, and the vegetation community characteristics of each subplot were recorded, which include species name, cover degree (total cover degree and species cover, which was visually estimated and marked in percentage), stand number, and average stand height. Aboveground and underground biomass samples were both collected, and the biomasses of the samples were weighed (i.e., fresh weight).

Vegetation samples were dried to a constant weight, weighed (i.e., dry weight) and then grinded. The remaining samples were used to measure the organic carbon content.

(2) Soil sample collection. In each subplot, the earth boring auger was used to collect soil samples of five layers (viz. 0–10, 10–20, 20–30, 30–50, 50–100 cm) with random arrangement for each boring and three replications. The soil samples from three replications were mixed at the same layers in each subplot. In this way total of 180 soil samples have been achieved. A 100 cm deep soil profile was excavated from each subplot, and the undisturbed soils were collected by using a cutting ring at the same layer depths as mentioned above. Two repetitions were made to measure soil bulk density for each layer.

The collected samples were naturally dried indoors. Plant residues, such as visually differentiable roots, were picked out from the soil samples. A part of the soil samples was used to measure soil moisture, while the others were used to measure the soil organic carbon content. The undisturbed soils obtained by the cutting ring were weighed (g_1), dried to a constant weight at 65℃, and then weighed again (g_2).

Table 1 Conditions of sampling plots

Planting time (yr)	Management pattern	Number of plots	Area of subplot	Geographic location	Altitude (m)	Slop (°)	Aspect
0	Cultivated sloping cropland	3	1m × 1m	106°03′29″N, 35°41′42″E	1816–2005	9	To sun, half to sun, and half to shade
2	Clipped for 2 years	3	1m × 1m	106°00′31″N, 35°28′01″E	2003–2018	6–9	half to sun, half to shade, and to shade
10	Clipped for 10 years	3	1m × 1m	106°00′32″N, 35°27′18″E	2003–2018	1–11	Two half to e sun and one to shade
10	Undisturbed for 10 years	1	1m × 1m	106°04′34″N, 35°45′47″E	2183	11	To sun
30	Abandoned grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years	2	1m × 1m	106°00′48″N, 35°27′53″E	2010–2015	9–18	Half to sun

(3) Sample determination. External heating, the dichromate oxidation method was used to measure the vegetation and soil organic contents.

2.3 Indicator value calculation

2.3.1 Importance value of vegetation community

Following Ren (1998), importance values of vegetation communities were calculated:

Importance value (IV) = (relative density + relative height + relative aboveground biomass)/3 × 100 (1)

Relative density = (density of a species / total density of all species) × 100 (2)

Relative height = (height of a species / total heightof all species) × 100 (3)

Relative aboveground biomass = (aboveground biomass of a species / total aboveground biomass of allspecies) × 100 (4)

2.3.2 Soil bulk density

Soil bulk density of the samples:

$$d = g_2 / v \tag{5}$$

where d is the soil bulk density (g/cm^3); g_2 is the undisturbed soil dry weight (g); and v is the volume of the cutting ring (100 cm^3 was used in our study).

2.3.3 Soil carbon stock

As depicted by Equation (6), the soil organic content and soil bulk density were used to calculate the soil carbon stock in each plot:

$$D = \sum D_i = \sum c_i B_i d_i \left(1 - \delta_{i2\text{mm}}\right) \tag{6}$$

where D is the total soil carbon stock at 100 cm soil layer with a 1 m^2 area, that is, the soil organic carbon density (SOCD) (kg/m^2). c_i, B_i, and d_i are the soil organic content (g/kg), soil bulk density (g/cm^3), and depth (cm) in layer i, respectively. $\delta_{i2\text{mm}}$ is the gravel with a diameter larger than 2 mm or the $CaCO_3$ concretion content (volume fraction) in layer i; and D_i is the soil carbon stock in layer i, where i = 1 to 5. Considering that almost no gravel or calcium carbonate concretion was found in the soils in the study area, $\delta_{i2\text{ mm}}$ can be neglected. Therefore, we obtained:

$$D = \sum D_i = \sum c_i B_i d_i \tag{7}$$

2.3.4 Vegetation carbon stock

Equation (8) shows that the organic carbon content of the vegetation samples was used to calculate the organic carbon stock of each plot:

$$D = c \times m \tag{8}$$

where D is the aboveground (or underground) organic carbon stock in 1 m^2 of vegetation (g/m^2); m is the dry weight of the aboveground and/or underground biomass (kg/m^2), and c is the organic carbon content of biomass (g/kg).

3 Results

3.1 Variations in vegetation composition of artificial grassland

During the early stage of planting, alfalfa (2 years) showed a remarkable growth trend and was the monodominant species of the grassland. Alfalfa degenerated after the vigorous growth period (10 years), and other species started to intrude. Thus, the number of plant species in the grassland increased. The artificial grassland was succeeded by the weed community with the constructive species of *S. bungeana* at 30 years (Table 2).

3.2 Effect of management patterns on vegetation biomass carbon stock

3.2.1 Variations in aboveground biomass carbon density

During the maturity period (10 years), the aboveground biomass of alfalfa and the total aboveground biomass carbon density of all vegetation (alfalfa + weeds) reached maximum values in the grassland clipped for 10 years, which were respectively 54.86 and 79.63 g/m^2. These densities were significantly higher ($p < 0.01$) than those of the grassland clipped for 2 years and the undisturbed grassland. Natural succession occurs when the alfalfa grassland is abandoned after the 10th year. In abandoned grasslands growing for 30 years, the average aboveground biomass carbon density of alfalfa was only 6.93 g/m^2, while the biomass carbon of the other weeds accounted for 81% of the total biomass carbon (Table 3).

Table 2 Plant composition of artificial alfalfa (*Medicago sativa L.*) grassland with different growing years

Growing year	Species number	Dominant species and importance value of alfalfa
2 years	3	*Medicago sativa L.* (97.33)
10 years	7	*Medicago sativa L.* (72.80), *S. bungeana*
30 years	8	*Medicago sativa L.* (22.20), *S. bungeana*, and *A. gmelinii*

Note: content in brackets indicate importance value of species

Table 3 Variation in aboveground biomass carbon density of artificial grassland under different management patterns (g/m^2)

	0 year (Cultivated sloping cropland)	2 years (Clipped)	10 years		30 years Abandoned grasslands growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years
			Clipped	Undisturbed	
Alfalfa	0 c	33.00 ± 3.87 b	54.86 ± 20.25 a	28.95 ± 7.83 b	6.93 ± 3.219 c
All vegetation	0 c	33.00 ± 3.87 b	79.63 ± 6.48 a	33.92 ± 5.61 b	36.42 ± 3.02 b

Note: one-way ANOVA, Duncan was used as post hoc

3.2.2 Variations in underground biomass carbon density

The root biomass carbon density remarkably exceeded that of the aboveground in the grassland. In the grassland clipped for 10 years, the root biomass carbon of alfalfa and all vegetation (alfalfa + weeds) were respectively 70.3% and 94% higher than those of the grassland undisturbed for 10 years. In the grassland clipped for 10 years, the root biomass carbon density of alfalfa (370.92 g/m^2) was significantly larger than those of the grassland clipped for 2 years (71.26 g/m^2) and the abandoned grasslands growing for 30 years (163.64 g/m^2) (Table 4).

3.3 Effect of management patterns on soil organic carbon stock

3.3.1 Variations in soil bulk density and organic carbon content

In grassland with the same management patterns, the soil bulk density of the different layers slightly increased from top to bottom (Table 5). In soils with different management patterns, the grassland clipped for 2 years had the maximal soil bulk density from 0 cm to 100 cm. The soil bulk density of the sloping cropland was minimal (Table 5).

The soil organic carbon determines the soil bulk density. The maximum organic carboncontent among all types of grassland soils was found in the 0 to 10 cm soil layer (Fig. 1). In deeper layers, the soil organic carbon became smaller as the soil depth was increased from 30 cm, which was consistent with dense root distribution and the high litter in the soil surface (Fig. 1). The soil organic carbon in every layer of grasslands increased with an increase in the growing years. The range of increase was not significant for the soils on the sloping croplands, grassland clipped for 2 years, and grassland undisturbed for 10 years (Fig. 1). The soil organic carbon in the grassland of these three management patterns were smaller than those of the grassland clipped for 10 years and abandoned grasslands growing for 30 years (Fig. 1).

Table 4 Variations in underground biomass carbon density of artificial grassland with different management patterns (g/m^2)

	0 year (Cultivated sloping cropland)	2 years (Clipped)	10 years		Abandoned grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years
			Clipped	Undisturbed	
Alfalfa	0 c	71.26 ± 8.19 c	370.92 ± 47.72 a	217.76 ± 60.15 b	163.64 ± 93.92 b
All vegetation	0 c	71.26 ± 8.19 c	427.27 ± 80.74 a	220.32 ± 52.23 b	251.51 ± 104.58 b

Note: *t*-test statistical analysis

Table 5 Soil bulk density on artificial alfalfa grassland under different management patterns (g/cm^3)

Soil depth (cm)	Cultivated sloping cropland	2 years (Clipped)	10 years		Abandoned grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years
			Clipped	Undisturbed	
0–10	1.15	1.16	1.14	1.17	1.16
10–20	1.19	1.23	1.12	1.13	1.19
20–30	1.09	1.24	1.22	1.12	1.17
30–50	1.07	1.27	1.24	1.20	1.13
50–100	1.19	1.27	1.24	1.22	1.18
Average	1.14	1.23	1.19	1.17	1.17

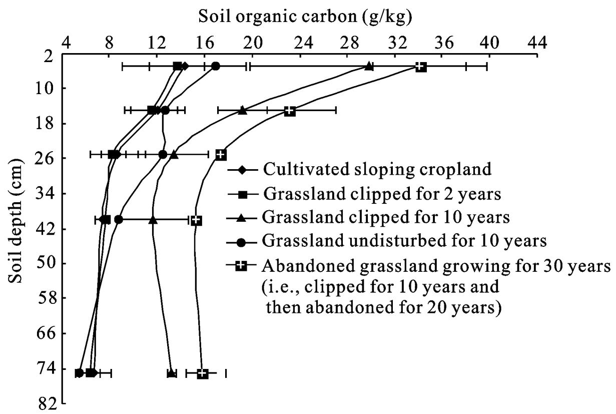

Fig. 1 Variations of organic carbon in soil layer from 0 cm to 100 cm under different management patterns

3.3.2 Variations in soil organic carbon density

In the artificial grassland, the SOCD in the soil layer from 0 cm to 100 cm increased over time. The SOCD reached 12.578 ± 0.863 kg/m^2 until the 30th year of the grassland succession, which was significantly higher than that of the sloping croplands and grasslands clipped for 2 years and 10 years (Table 6). The SOCD on grassland clipped for 10 years was 10.215 ± 2.166 kg/m^2, which was significantly larger than those of the grassland clipped for 2 years (Table 6). These results indicate that the SOCD from 0 cm to 100 cm of the artificial grassland increased over time.

3.4 Variation in grassland ecosystem carbon density under different management patterns

The ecosystem carbon density of the undisturbed grassland and the abandoned grassland increased over time. The ecosystem carbon densities of the grassland clipped for 10 years and the abandoned grasslands growing for 30 years were significant higher than that of the sloping croplands (Table 7). As depicted by Table 7, the average proportion of the soil carbon density to the ecosystem carbon density was 99.4%, i.e., the soil carbon is the main component of the ecosystem carbon stock (Table 7).

4 Discussion

4.1 Effect of clipping and abandonment on biomass carbon stocks of artificial grassland

The alfalfa was the dominant species on the artificial grassland in the first 10 years of the growth, and the overall clipping of the grassland was once or twice a year because of the demand for fodder. In the first 10 years, the biomass carbon increased over time. The biomass carbon density, which is the total biomass including aboveground and underground biomass, of the grassland clipped for 10 years was 425.78 g/m^2 (aboveground and underground biomass were 54.86 g/m^2 and 370.92 g/m^2, respectively; Table 3 and 4) which was 3.1 times to that of the grassland clipped for 2 years and 2.7 times to that of the grassland undisturbed for 10 years.

After 10 years of growth, the alfalfa populations declined, and weeds intruded into the alfalfa community, which led to community succession. Compared to the grassland clipped for 10 years, the alfalfa biomass car-

Table 6 Variations of soil organic carbon density in each soil layer on grassland with different management

Soil depth(cm)	Soil organic carbon density (kg/m^2)			
	0 year (cultivated sloping cropland)	Grassland clipped for 2 years	Grassland clipped for 10 years	Abandoned grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years
0–10	0.959 ± 0.604 c	0.920 ± 0.213 c	1.415 ± 0.655 b	2.297 ± 0.320 a
10–20	0.813 ± 0.264 c	0.827 ± 0.307 c	1.246 ± 0.227 b	1.703 ± 0.770 a
20–30	0.551 ± 0.258 c	0.598 ± 0.123 c	1.115 ± 0.406 b	1.179 ± 0.138 a
30–50	0.920 ± 0.125 d	1.131 ± 0.131 c	1.664 ± 0.626 b	2.004 ± 0.048 a
50–100	2.305 ± 0.881 c	2.335 ± 0.586 c	4.775 ± 0.262 b	5.395 ± 0.041 a
$\sum_{0-100}$	5.300 ± 0.981 d	5.973 ± 0.044 c	10.215 ± 2.166 b	12.578 ± 0.863 a

Note: one-way ANOVA, Duncan was used as post hoc

Table 7 Variations of ecosystem carbon density of artificial grassland under different management patterns (kg/m^2)

Growing year	0 year (cultivated sloping cropland)	Grassland clipped 2 years	10 years		Abandoned grassland growing for 30 years, i.e., clipped for 10 years and then abandoned for 20 years
			Clipped	Undisturbed	
Carbon stock	5.300 ± 0.981 b	6.18 ± 0.30b	10.30 ± 1.26 a	6.00 b	12.62 ± 0.50 a

Note: for *t*-test statistical analysis

bon density and the total biomass carbon density in the grassland abandoned for 30 years reduced 59.9% and 43.2%, respectively. The biomass carbon density of the grassland undisturbed for 10 years was lower than that of the grassland clipped for 10 years. Therefore, clipping has a significant effect on the grassland biomass carbon stock in the vigorous growth period of alfalfa (Bao *et al*., 2004). The alfalfa further degenerated and the weeds gradually became dominant in the process of succession for community, which greatly reduced the grassland biomass carbon. Although several studies have shown that weed invasion can increase community biomass (Gao *et al*., 2009; Tang *et al*., 2012), this study showed that the biomass carbon stocks did not increase after the alfalfa grasslands had been abandoned. The mechanism of this phenomenon can be attributed to the degeneration of the alfalfa populations and the invasions of weeds which have often little biomass (Shao *et al*., 2009; Zhang, 2010), which results in a lower total community biomass because of the biological characteristics.

In our study, the utilization with low severity such as low-frequency clipping or light grazing often consumes about one-fifth of plant production in terrestrial ecosystems (Cyr and Pace, 1993). Hence, they can have positive effects on plant production by changing plant photosynthetic rate, growth rate, photosynthetic product allocation, and/or releasing plant from apical dominance (Strauss and Agrawal, 1999; Bagchi and Ritchie, 2011). Consequently, the utilization with low severity can promote plant growth, which increases aboveground/underground biomass and subsequent litters. This could be the reason why the alfalfa grasslands treated with low-severity clipping (clipped for 2 years) have higher soil organic carbon than both 1) undisturbed alfalfa grasslands and 2) the grassland which has been clipped for 10 years and then abandoned.

4.2 Effect of clipping and abandonment on ecosystem carbon stock on artificial grassland

The sloping croplands had the smallest SOCD than all grassland soils, which may be attributed to the fast decomposition of organic carbon after long-term farming (Yan *et al*., 2008). The soil organic carbon of grassland in the soil layer from 0 cm to 50 cm was higher than that in the soil layer from 50 cm to 100 cm. This result demonstrates the reduction in soil organic carbon with the increasing of soil depth due to the fact of the reduced input of organic carbon in deeper soil (Bao *et al*., 2004). The organic carbon in the soil layer from 0 cm to 100 cm increased along with the growing years. In the early growth stage (1 to 2 years) of alfalfa, the grassland soil organic carbon stock was smaller than those of the grasslands clipped for 10 years and abandoned grasslands growing for 30 years because of the relatively small amount of dead roots and the reduction of litter from the clipping harvest. The soil organic carbon reached the maximal value after 30 years of the alfalfa grassland development. This result is similar to that of the study in low-rainfall regions (Jackson *et al*., 2002), where the year-long average rainfall was approximate 450 mm. The low rainfall influenced the SOCD, enzymatic activity, and chemical properties of organic functional groups, which led to in the accumulation of carbon.

The biomass carbon (aboveground and underground) of the abandoned grassland had the maximal value after the clipping reached 10 years. This value declined to 30 years of the abandonment. However, the soil organic carbon of the grassland increased with prolonged time and changed on different grassland management patterns. Considering that the increased soil carbon offset the effect of the reduced biomass carbon on the total carbon stock of the ecosystem, the total carbon stock of the ecosystem increased, i.e., the soil organic carbon plays a vital role in the carbon sequestration of the grassland ecosystem.

Management pattern can change plant biomass and subsequent litter quantity, and then influence growing conditions of microbe. In other words, management pattern can change the microbe metabolism and community composition and thus influence ecosystem carbon cycle. The utilization with low severity may improve the rhizosphere effect, which could promote the plant growth and then improve the carbon cycle.

5 Conclusions

Artificial alfalfa grassland is one of the important land types in the vegetation restoration of the Loess Plateau. During the maturity period of this grassland (0 to 10 years), clipping was conducive to biomass carbon accumulation of the plant community (aboveground and underground). The grassland was then abandoned.

Weed intrusion led to community succession, which impaired the accumulation of the biomass carbon of the plant community. The average soil organic carbon density in soil layer from 0 cm to 100 cm increased over time. Thus, the ecosystem carbon density of the alfalfa grassland increased over time due to the fact that the soil organic carbon is the key form of the ecosystem carbon stock. These results proved that the growing time and management patterns can significantly influence grassland carbon stock.

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