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Mini Review

Prospects of Grassland Carbon Sink in Inner Mongolia, China

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Abstract

Grassland is one important terrestrial ecosystem to play the essential role in global carbon cycle. With vast grassland, Inner Mongolia is one important base of animal husbandry in China. Due to irrational and immoderate cultivation and overgrazing, grassland degradation has become a severe issue for grassland ecosystem protection, as well as sharp decreasing of grassland carbon pool. However, through effective and efficient management practices, grassland ecosystem can be improved, degraded grassland can be restored, grassland carbon pool can be reinstated, and economic values of grassland carbon sink can be promoted. In this study, first, the situation of grassland degradation in Inner Mongolia was analyzed and carbon sink potential of degraded grassland was evaluated. Second, in order to choose the most suitable grassland management practices for different vegetation types, three representative sites, Siziwangqi (desert steppe), Maodeng Pasture Farm (typical steppe) and Etuokeqianqi (degraded grassland restoration), were selected to assess the effectiveness and efficiency of various grassland management practices. Finally, some suggestions for grassland management and carbon pool enhancement were proposed, accordingly.

Keywords: Grassland carbon sink; Grassland degradation; Grassland carbon pool; Grassland management practice

Introduction

Carbon sink is the pool to absorb and store carbon-containing chemical compound for an unspecified time, which can be natural sinks (such as ocean, forest and grassland) and artificial sinks (such as landfills). Whilst encountering severe challenges to the world's sustainable development, carbon sink, as an offset to carbon emissions stipulated in the Kyoto Protocol, has become the significant means for climate change mitigation.

Grassland is the most widespread vegetation type to cover almost one-fifth of the earth land surface. As one of the important terrestrial ecosystems, grassland ecological system plays the essential role in terrestrial carbon cycle and carbon pool. According to estimation, the grassland carbon pool is around 308,000TgC (1Tg = 10^{12}g), accounting for 15.2% of total terrestrial carbon pool, where 91.6% (282,000TgC) is stored in soil and 8.4% (26,000TgC) is stored in biomass [1-3]. Owing to human activities, such as overgrazing and cultivation, considerable portions of the grasslands have been degraded to transfer significant amount of soil carbon into the atmosphere, all over the world. However, good grassland management has great potential to minimize carbon losses and sequester carbon in soils. In addition, implementing improved grassland management practices and rehabilitating degraded grasslands would build or rebuild soil carbon pools in grasslands and reduce the concentration of carbon dioxide (CO_2) in the atmosphere, which could lead to substantial benefits of mitigation, adaptation and development [4-7].

Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), China has committed to reduce its national CO_2 emissions per unit gross domestic product (GDP), carbon intensity, by 40~45% from 2005 levels, by 2050. Accordingly, carbon intensity should be reduced 17% by 2015 in comparing with 2010 levels. On November 9th, 2011, the Work Programs of Greenhouse Gases (GHGs) Emission Control for the 12th Five-Year Plan for National Economic and Social Development (12th Five-Year Plan) was promulgated during the executive meeting of the State Council to explicitly confirm the general requirements and key tasks of GHGs emission control in China. Additionally, as indicated in Some Opinions of the State Council on Promoting Sound and Fast Pastoral Areas Development, the major tasks of pastoral development are to integrate grassland ecosystem protection with increasing the incomes of herdsmen, to provide subsidy and incentives for sound grassland management (such as enclosure and forage-livestock balance), to ensure the incomes of herdsmen while reducing the amount of livestock, and to stimulate the aggressiveness of herdsmen for grassland ecosystem protection. Hence, increasing forest and grassland carbon sink has become the important means to offset carbon emissions in China.

Second to Australia, the area of the grasslands in China is about 3.93×10^{6} km^{2} to account for 12.5% of the total grasslands in the world and 41.7% of the total area of China. Most of the natural grassland in China is temperate steppe spreading in western, northwestern and northern parts of the country, including Tibet (20.9%), Inner Mongolia (20.1%), Xinjiang (14.6%), Qinghai (9.3%), Sichuan (5.7%), Gansu (4.6%) and Yunnan (3.9%), to account for more than 78.6% of the total natural grassland in China, as shown in Table 1 [8-11]. According to 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories [12], the potential of grassland carbon sequestration is about 130tC/km^{2}•a. Thus, the potential of grassland carbon sequestration in China is around 520TgC, which is 1.91×10^{9}t CO_2 e. Based on the World carbon dioxide emissions data by country, the total CO_2 emissions of China in 2009 is 7.71×10^{9}t CO_2 e [13]. Apparently, in China, grassland carbon sequestration can offset one quarter of the national CO_2 emissions, annually. Unfortunately, due to overgrazing and cultivation, great portions of the grasslands are under different degrees of degradation to release considerable amount of carbon originally stored and sequestrated. Nevertheless, grassland vegetation can be recovered rapidly through some proper grassland management practices. Therefore, there is great potential to recover carbon losses and sequester substantial amount of carbon in soils through improving grassland management practices.

The grassland in Inner Mongolia is the typical mid-latitude arid and semi-arid temperate grassland, which is one of the most important bases of animal husbandry industry, in China. As pointed out in Some Opinions of the State Council on further Promoting Sound and Fast Economical and Social Development in Inner Mongolia, the key works are promoting ecological construction and environmental protection, realizing energy conservation and emission reductions, developing circular economy, deploying pilot projects of emission permit, compensation for use and emissions trading on major pollutants, promoting wide applications of low carbon technology, implementing demonstration projects of forest and grassland carbon sequestration, and carbon sink technology, and applying GHGs emission control. In addition, as specified in the 12th Five-Year Plan for National Economic and Social Development of Inner Mongolia (the 12th Five-Year Plan of Inner Mongolia), the primary missions are constructing the bases of forest carbon sink, enhancing the capacity of grassland carbon sink, establishing the evaluation standard system for grassland carbon sequestration, developing trading market of grassland carbon sink, and promoting carbon sink trading.

However, presently, the researches on the grassland carbon sink of Inner Mongolia are still at the initial stage. There are lack of studies and practices on policy measures, trading model, methodology, fundamental information and related basic data. Thus, it is of great significance to study the grassland carbon sink of Inner Mongolia. In this study, grassland carbon pools and carbon sink potential in Inner Mongolia were evaluated, firstly. Several typical regions with various management schemes, including Siziwangqi (in Wulanchabu), Maodeng Pasture Farm (in Xilinguole) and Etuokeqianqi (in Erdos), were selected for site survey, secondly. Some recommendations were proposed for the improvement of grassland management practices, policies and decision making process, at last.

Measurement of Grassland Carbon Pool

According to IPCC [12], the grassland ecosystem can be divided into two parts, such as woody perennials and herbaceous perennials. For woody perennials, the changes of plant carbon pools should include both above ground and underground parts. But for herbaceous perennials, the changes of plant carbon pools should include underground part, only. Based on the methods recommended by this Guidelines, grassland carbon pool can be calculated by the following equations.

$$G_{PCDi} = G_{NPPi} \times G_{PCi}$$

$$G_{SCDi} = h_i \times B_i \times G_{SCi}$$

Where, G_{PCDi} is the carbon density of i type of grassland vegetation (kg/km^{2}); G_{NPPi} is the net primary production (NPP) (dry weight) of i type of grassland vegetation (kg/km^{2}); G_{PCi} is the plant organic carbon (POC) content of i type of grassland vegetation (%); G_{SCDi} is the soil carbon density of i type of grassland vegetation (kg/km^{2}); h_i is the depth of soil bulk density of i type of grassland vegetation (m); B_i is the average soil bulk density of i type of grassland vegetation (g/cm^{3}); and G_{SCi} is the soil organic carbon (SOC) content of i type of grassland vegetation (%).

$$G_{Ti} = G_{Pi} + G_{Si}$$

$$G_{Pi} = G_{Pagi} + G_{Pugi}\ (G_{Pugi} = G_{Pagi} \times R)$$

$$G_{Pagi} = G_{PCDi} \times S_i$$

$$G_{Si} = G_{SCDi} \times S_i$$

Where, G_{Ti} is the total organic carbon (TOC) of i type of grassland vegetation (tC); G_{Pi} is the POC of i type of grassland vegetation (tC); G_{Si} is the SOC of i type of grassland vegetation (tC); G_{Pagi} is the above ground POC of i type of grassland vegetation (tC); G_{Pugi} is the underground POC of i type of grassland vegetation (tC); R is the ratio of C_{Pugi} to C_{Pagi}; and S_i is the area of i type of grassland vegetation (km^{2}).

Measurement of Grassland Carbon Pool in Inner Mongolia

As indicated in Table 1, the area of the grassland in Inner Mongolia is 788.0×10^{3}km^{2} with available grassland of 635.9×10^{3}km^{2}. Wherein, the biggest part is typical steppe with an area of 311.9×10^{3}km^{2}, accounting for about 49.0%. Meadow, desert steppe and meadow steppe account for 16.9%, 15.3% and 10.7%, respectively. The smallest part is marshland accounting for about 6.2%, as shown in Table 2 [14].

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Table 1: Major grassland distribution in China.

Administrative District	Total Grasslands		Available Grasslands	
	(10^3 km^2)	(%)	(10^3 km^2)	(%)
CHINA	3,928.3	100.0	3,310.0	84.3
Tibet	820.5	20.9	708.5	86.4
Inner Mongolia	788.0	20.1	635.9	80.7
Xinjiang	572.6	14.6	480.1	83.9
Qinghai	363.7	9.3	315.3	86.7
Sichuan	225.4	5.7	196.3	87.1
Gansu	179.0	4.6	160.8	89.8
Yunnan	152.7	3.9	118.7	77.7

Table 2: Distribution of temperate grassland in Inner Mongolia.

Vegetation Type	Area (10^3 km^2)	Apportion (%)
Typical steppe	311.9	49.0
Meadow	107.3	16.9
Desert steppe	97.2	15.3
Meadow steppe	68.3	10.7
Marshland	39.7	6.2
TOTAL	624.4	98.2

Plant organic carbon pool

According to the field survey data of grassland in Inner Mongolia, the average above ground biomass density (BD_{ag}) of grassland is 48.11 gC•m^{-2}, and the average underground biomass density (BD_{ug}) of grassland is 292.86gC•m^{-2}. Meadow steppe has the highest biomass density, where BD_{ag} and BD_{ug} are 82.52 gC•m^{-2} and 513.33gC•m^{-2}, accordingly. Desert steppe has the lowest biomass density, where BD_{ag} and BD_{ug} are 20.28gC•m^{-2} and 121.55 gC•m^{-2}, respectively, as shown in Table 3. Since the area of marshland is quite small, the carbon pool of marshland ecosystem was not estimated in this project.

Table 3: Grassland POC pool in Inner Mongolia.

Vegetation Type	BD_{ag}	BD_{ug}	POC_{ag}	POC_{ug}	POC_T
	(g C/m^2)	(g C/m^2)	(T gC)	(TgC)	(TgC)
Typical steppe	46.52	265.65	14.51	82.86	97.37
Meadow	56.05	386.80	6.01	41.50	47.52
Desert steppe	20.28	121.55	1.97	11.81	13.79
Meadow steppe	82.52	513.33	5.64	35.06	40.70
Average	48.11	292.86	-	-	-
Total	-	-	28.13	171.23	199.37

The estimated grassland POC pool (POC_T) in Inner Mongolia is 199.37TgC, where the above ground biomass (POC_{ag}) and underground biomass (POC_{ug}) are 28.13TgC (14.1%) and 171.23TgC (85.9%), respectively. The POC pool of typical steppe is 97.37TgC, accounting for 48.8%, where the POC_{ag} and POC_{ug} are 14.51TgC and 82.86TgC, respectively. The POC pools of meadow, meadow steppe and desert steppe are 47.52TgC (23.8%), 40.70TgC (20.4%) and 13.79TgC (6.9%), as listed in Table 3.

Soil organic carbon pool

According to the field survey data of grassland in Inner Mongolia, the average natural grassland SOC density at 0-30cm and 0-100cm are 4.00kgC•m^{-2} and 6.67kgC•m^{-2}, respectively. The SOC densities of typical steppe, meadow, desert steppe and meadow steppe, at 0-30cm are 4.00kgC•m^{-2}, 3.81 kgC•m^{-2}, 2.30 kgC•m^{-2} and 6.68kgC•m^{-2}, accordingly. The SOC densities of typical steppe, meadow, desert steppe and meadow steppe, at 0-100cm are 7.06kgC•m^{-2}, 4.69kgC•m^{-2}, 4.01kgC•m^{-2} and 11.80kgC•m^{-2}, correspondingly, as illustrated in Table 4.

Based on estimation, grassland SOC pool in Inner Mongolia at 0-100 cm is 3,901TgC, where 59.9% is contributed from SOC pool at 0-30 cm. Wherein, the SOC pool of typical steppe at 0-100 cm is the highest share to account for 56.4% of total grassland SOC pool in Inner Mongolia. And the SOC pools of meadow, desert steppe and meadow steppe account for 12.9%, 10.0 % and 20.7%, respectively, as presented in Table 4. According to a recent study reported, grassland SOC pool in northern China at 0-100cm is 16,670TgC. Thus, grassland SOC pool in Inner Mongolia is about 23.4% of total grassland SOC pool in northern China.

Table 4: Grassland SOC pool in Inner Mongolia.

Vegetation Type	SOC Density (kgC/m^2)		SOC Pool (TgC)	
	0-30cm	0-100cm	0-30cm	0-100cm
Typical steppe	4.00	7.06	1,247.60	2,202.01
Meadow	3.81	4.69	408.81	503.24
Desert steppe	2.30	4.01	223.56	389.77
Meadow steppe	6.68	11.80	456.24	805.94
Average	4.00	6.67	-	-
Total	-	-	2,336.22	3,900.96

Total grassland carbon pool

Based on the calculation of grassland POC pool and SOC pool, the total carbon pool of temperate grassland in Inner Mongolia is 4,100.3TgC, where the carbon pool of typical steppe is the largest one (2,299.4TgC) to account for 56.1%, due to the area is the biggest. The carbon pools of meadow, desert steppe and meadow steppe are 550.8TgC (13.4%), 403.5TgC (9.8%) and 846.6TgC (20.6%), respectively, as demonstrated in Table 5.

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Table 5: Total grassland carbon pool in Inner Mongolia.

Vegetation Type	POC Pool (TgC)	SOC Pool (TgC)	TOC Pool (TgC)
Typical steppe	97.37	2202.01	2,299.38
Meadow	47.52	503.24	550.76
Desert steppe	13.79	389.77	403.56
Meadow steppe	40.70	805.94	846.64
Subtotal	199.37	3900.96	4,100.33

Potential for Grassland Carbon Pool Increment in Inner Mongolia

In recent years, significant portions of grassland have been degraded resulted from long-term large-scale human activities (such as overgrazing, cultivation, indiscriminate development, estrepement and other irrational activities) or continuous deterioration of natural conditions to release great amount of carbon originally sequestrated. At present, the area of degraded grassland in Inner Mongolia is 250.37×10^{3}km^2 to account for 39.4% of the area of entire available grassland in Inner Mongolia (635.91×10^{3}km^2), where the areas of severely, moderately and light degraded grassland are 43.58×10^{3}km^2, 88.43×10^{3}km^2 and 118.36×10^{3}km^2, accounting for 17.4%, 35.3% and 47.3% of the area of degraded grassland, correspondingly. In addition, there are seven administrative districts where degraded grassland is over 50%, including Wulanchabu, Erdos, Chifeng, Tongliao, Baotou, Huhehaote and Wuhai, as shown in Table 6 [11]. Therefore, in order to prevent further grassland deterioration and degradation, to mitigate degraded grassland and to significantly improve grassland carbon pool in Inner Mongolia, it is necessary to strengthen the grassland management practices for degraded grassland restoration and improvement of grassland carbon sequestration.

Table 6: Status of grassland degradation in Inner Mongolia.

Administrative District	Available Grassland	Total Degraded Grassland		Light Degraded		Moderate Degraded		Severe Degraded	
	(10^3 km^2)	(10^3 km^2)	(%)	(10^3 km^2)	(%)	(10^3 km^2)	(%)	(10^3 km^2)	(%)
Xilingolite	176.61	72.86	41.3	34.72	47.7	29.94	41.1	8.19	11.2
Hulunbeier	99.81	20.97	21	11.87	56.6	7.19	34.3	1.92	9.2
Alashan	97.86	15.61	16	8.278	53	7.03	45.1	0.3	1.9
Wulanchabu	50.84	26.15	51.4	15.16	58	6.26	23.9	4.74	18.1
Erdos	47.89	30.82	64.4	11.48	37.3	13.08	42.4	6.25	20.3
Chifeng	46.41	29.32	63.2	9.8	33.4	11.04	37.7	8.48	28.9
Bayannaoer	46.24	18.67	40.4	13.81	73.9	4.2	22.5	0.66	3.6
Tongliao	37.14	24.14	65	8.08	33.5	6.73	27.9	9.34	38.7
Xingan	26.12	7.59	29	3.06	40.3	1.95	25.7	2.58	34.1
Baotou	4.24	2.53	59.5	1.36	53.9	0.39	15.3	0.78	30.7
Huhehaote	1.49	0.91	61.1	0.27	30	0.3	32.8	0.34	37.2
Wuhai	1.25	0.8	63.9	0.48	60	0.32	40	-	-
TOTAL	635.91	250.37	39.4	118.36	47.3	88.43	35.3	43.58	17.4

Indeed, grassland vegetation can be rapidly recovered through proper grassland management practices. Hence, the potential of grassland carbon pool increment is very huge. Since the application of some grassland management practices, including enclosure, banning grazing, deferred grazing and rotational grazing, the conditions of degraded grassland have been greatly improved to significantly elevate the grassland carbon pool in Inner Mongolia.

The potential for grassland carbon pool increment is the amount of carbon sequestered by grassland when the degraded grassland is restored. Based on the Parameters for Degradation, Desertification and Salinization of Rangeland (GB 19377-2003) and the Technical Guide for Grade Assessment of Natural Grassland (NY/T 1579-2007), the potential for grassland carbon pool increment can be obtained through the following steps. First is to calculate the possible increment of total grassland yields through multiplying POC_{ag} by the declining proportion of total grassland yields. Second is to multiply the possible increment of total grassland yields by the area of degraded grassland to get the potential for POC_{ag} increment. Third is to calculate the potential POC_{ug} increment by root-shoot ratio. Fourth is to calculate the potential for grassland POC increment by adding the potential for POC_{ag} increment and the potential for POC_{ug} increment together. Last is to add the potential for grassland SOC increment to calculate the potential for grassland carbon pool increment.

According to the field survey data of grassland in Inner Mongolia, typical steppe has the highest potential for grassland POC increment (10.76TgC/yr), the highest potential for grassland SOC increment (13.31 TgC/yr for forage-livestock balance and 10.96TgC/yr for fully enclosure). Also, the potential for increasing carbon pool of degraded grassland in Inner Mongolia is estimated between 43.56 to 48.16TgC, annually, as shown in Table 7.

Table 7: Potential for grassland carbon pool increment in Inner Mongolia.

Vegetation Type	Degraded Area	Potential for POC Increment (TgC/yr)			Potential for SOC Increment (TgC/yr)	
	(10^3 km^2)	POC_{ag}	POC_{ug}	POC_T	Fully Enclosure	Forage-Livestock Balance
Typical steppe	133.54	1.75	9.99	11.74	10.96	13.31
Meadow	45.96.	0.73	5.01	5.74	3.6	4.36
Desert steppe	41.6	0.24	1.43	1.66	0.95	1.58
Meadow steppe	29.23	0.68	4.22	4.9	4.01	4.87
TOTAL	250.32	3.4	20.64	24.04	19.52	24.12

Analysis on Various Management Practices on Degraded Grassland in Inner Mongolia

Grassland carbon pool can be built and rebuilt through improved and rational management practices, such as enclosure, rotational grazing, artificial planting [4-6,15]. In order to restore degraded grassland in Inner Mongolia, various grassland management practices have been implemented to make grassland more resilient to climate change, to increase grassland carbon pool and to elevate grassland yields. Several areas with different vegetation types were chosen for field survey to examine the changes of carbon pools under diverse management practices. Furthermore, investigation and analysis were performed on selective but representative vegetation types with diverse grazing management practice to evaluate the current conditions and potential for increasing carbon pool of typical grassland in Inner Mongolia, including reducing grazing pressure on desert steppe in Siziwangqi (Wulanchabu), enclosure on typical steppe in Maodeng Pasture Farm (Xilinguole), and restoration on degraded grassland in Etuokeqianqi (Erdos) [16].

Grazing management schemes pilot site on desert steppe in Siziwangqi

Based on the studies, heavy grazing will significantly reduce the POC_{ag} of desert steppe. The POC_{ag} in control plot and light grazing plot are significantly higher than that in heavy grazing plot. Root system of vegetation in desert steppe is mainly concentrating in topsoil at the depth 0-20cm. The proportions of biomass of topsoil root system to biomass of total root system for control, light grazing, moderate grazing and heavy grazing plots are 56%, 59%, 55%, and 55%, respectively. Especially, light grazing will facilitate the increase of underground biomass at the depth of 0-20cm [17].

In order to analyze the difference of carbon sequestration between various vegetations in desert steppe, Caragana intermedia, Caragana microphylla Lam. and Alfalfa were planted to analyze their biomass. As a result, carbon sequestrations of artificial grassland are much higher than that of enclosed natural grassland in desert steppe, as listed in Table 8. Therefore, it will increase the potential of grassland carbon sequestration in desert steppe by promoting artificial grassland [18].

Table 8: Carbon sequestration of different artificial vegetation in desert steppe.

Artificial Vegetation	Root System (10^3 kg/km^2)	Above Ground Vegetation (10^3 kg/km^2)	Total Vegetation (10^3 kg/km^2)
Caragana intermedia	1173.51±475.63 A	189.59±80.99 C	1363.10±554.96 A
Caragana microphylla Lam.	956.97±508.45 B	187.39±81.63 C	1144.36±478.57 A
Alfalfa	829.89±488.89 B	548.23±29.69 A	1378.12±492.72 A
Enclosed natural grassland	128.40±62.86 D	146.20±10.86 D	274.60±57.13 C

Note: Different characters represent significant difference at $p<0.05$.

Enclosure pilot site on typical steppe in maodeng pasture farm

According to long-term fixed position monitoring data, carbon pools characteristics, process and mechanisms of typical steppe can be summarized as the followings.

A. For typical steppe, the POC_{ag} per area and height of communities decrease with the increasing of degradation degree, as listed in Table 9.

Table 9: The POC_{ag} per area and height of community in typical steppe.

Sample Plot	Community Type	POC_{ag} per area (g/m^2)	Community Height (Cm)
Serious degraded	*Artemisia frigida*	113.98	4.94

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Restored for 10 years	*Agropyron*	236.66	31.61
Restored for 23 years	*Stipa grandis*	280.98	32.66

B. The SOC of degraded communities were significantly lower than that of restored communities. Obviously, restored vegetation can greatly increase the TOC of grassland ecosystem.

The reduction of the SOC of degraded grassland is mainly allocated in topsoil at the depth of 0-10cm. The SOC at other depths are relatively stable. Grazing process, especially heavy grazing, will significantly increase the coefficient and amount of surface runoff to result in soil erosion. Soil erosion may have impacts on the SOC, topsoil carbon pools mainly, which is the important factor causing variations on the TOC of degradation grassland.

Restoration pilot site on degraded grassland in etuokeqianqi

In Etuokeqianqi, the Husbandry Economy Development Plan for Three Zones was fully implemented in 2010. The term "Three Zones" means the entire county was categorized into three different zones, including the agriculture and animal husbandry area for optimistic development, agriculture and animal husbandry area for restricted development, and the area prohibited for development. Based on the field survey in combining with interview with representatives from counties, towns, villages, and herdsmen, the qualitative evaluation on the potentials of grassland carbon sink under various management practices were conducted for Three Zones.

Inorder to assess the most favorable measure for highest potential of grassland carbon sink, seven different indicators were applied in the assessment, including TOC potential, cost, required post management, risk, feasibility of promotion, policy support and current organizations. Six different practices were selected, including Caragana tibetica preservation in enclosed area (Practice A), artificial planting Caragana intermedia in enclosed grazing banning area (Practice B), solar power greenhouse agriculture (Practice C), Alfalfa for forage base (Practice D), base of species improvement for animal husbandry, especially for sheep and goats (Practice E), and the Malan Flower Planting Base in the Shanghai Temple Coal Chemical Industrial Park (Practice F), to conduct quantitative comparisons. Through comparative analysis, Practice B, with highest TOC potential, moderate cost, lowest requirement for post management, lowest risk, highest feasibility of promotion and policy support, was evaluated as the highest potential for the development of carbon sink in Etuokeqianqi, as shown in Table 10.

Table 10: Evaluations on carbon sink potential under different practices in Etuokeqianqi.

Management Practice	TOC Potential	Cost	Required Post Management	Risk	Feasibility of Promotion	Policy Support	Current Organizations
A	1	5	1	1	1	P	Government Management
B	5	3	1	1	5	P	Government + Herdsmen
C	4	5	4	4	2	P	Government + Herdsmen
D	1	4	4	4	2	P	Government + Cooperation
E	5	5	5	5	?	?	Herdsmen
F	1	5	5	5	?	P	Government Management

Discussion

As described in Section 1, the primary missions for Inner Mongolia during the 12th Five-Year Plan are to construct the bases of forest carbon sink, to enhance the capacity of grassland carbon sink, to establish the evaluation standard system for grassland carbon sequestration, to develop trading market of grassland carbon sink and to promote carbon sink trading. Many measures and practices have been implemented in trying to fulfill these targets along with assistance from appropriate incentives and motivations, for example, ecological compensations mechanism (a passive approach) and carbon trading market (a progressive approach).

In China, ecological compensations mechanism has been implemented for more than 20 years with considerable achievements. However, it requires enormous cash flow and capital investment from the Governments and tremendous efforts from all participants, which is not long-term sustainable, at all. On the other hand, under the context of CO_2 emissions reduction, carbon trading market can be long-term feasible and sustainable. However, currently, China's carbon trading market is quite immature attributed to some major issues summarized in the followings, based on many fruitful researches and investigations, worldwide.

A. Lack of relevant national policies and regulations to provide legally binding force

B. Lack of quantitative assessment methods of grassland carbon sequestration value

C. Lack of normative measurement and monitoring technology system for grassland carbon sink

D. Lack of long-term and effective financial support

E. Lack of relevant professional and technical personnel

F. Lack of third-party validation and verification mechanism

G. Lack of market demands due to no policy support

Some recommendations on policies and measures for grassland carbon trading system were then drawn accordingly.

Establish the legal status of grassland carbon sink

In China, grassland carbon sink is one of the essential factors for national economic development and can play an important role in attaining the crucial position for the allocation of CO_2 emission permits, internationally. Currently, in addition to the Grassland Law of the People's Republic of China (the Grassland Law), Returning Farmland to Grassland and Returning Pasture to Grassland, there are no relevant laws, regulations and rules concerning grassland carbon sink. Therefore, it is necessary to clearly define the importance and legality of grassland carbon sink through the institution of relevant laws and regulations.

Found compensatory transfer payment mechanism for grassland carbon trading

First is to establish the evaluation index system to scientifically evaluate carbon emissions and carbon sequestration of a region and the balance of carbon sink. Second is to establish interest coordination mechanism. In order to provide incentives for both buyers and suppliers, it is necessary to develop carbon market so the underdeveloped areas can acquire the compensatory transfer payment from developed areas, through market mechanisms, for example, through taxation measures, to collect emission fees from carbon emissions sources and to compensate the entities generate carbon sinks; or, to facilitate carbon trading between carbon sources and carbon sinks by trading carbon credits. Third is to establish the comprehensive compensation mechanism for grassland ecosystem restoration to offer subsidy and rewards to the construction of grassland carbon sink base for grassland ecological protection.

Establish emission permits system to facilitate carbon offset

Government should allow enterprises, based on the emission permits and the costs of emission reductions, to freely select various means for their emission reductions, for example, to reduce the emissions by themselves, to purchase emission quota from other enterprises, to purchase carbon credits through carbon sinks, or any combinations of the above. In addition, the acquired carbon credits can be used to offset the possible obligatory emission reductions allocated in the future. Hence, carbon sinks purchased by enterprises at present can be stored as the quota for future emission or the offset for future obligatory emission reductions.

Establish simple trading system and trading standards

A standardized contract, the most important and critical issue for carbon trading market, should be designed and applied. During the institution of the standardized contract, first is to make every party of the trade clearly understand each provision of the contract, including liability for losses, shared responsibility for project risks, interest allocation, and etc., to prevent any opportunistic behaviors. Second, in order to reduce the trading costs of market operation and to promote the development of grassland carbon market, it is necessary to clearly specify the trading system and trading rules in the contract to increase the transparency of information and to reduce the uncertainty of trading.

Establish a complete system for monitoring, measurement and validation

First is to determine emission reductions through directly measuring the amount of carbon sequestration, or model estimations on GHGs emission reductions in the atmosphere through improving management schemes. Second is to reduce the monitoring costs so herdsmen can acquire certificate of carbon sink credits through validation, authentication, enrollment and registration. Third is to identify the organizations of measurement, monitoring, validation and certification for carbon sources and carbon sinks. The measurement and monitoring organizations cannot be the certification organizations. And the government institutes or the departments organizing the production of carbon sinks cannot be the certification organizations, which should be the independent social groups.

Initiate the platform for grassland carbon trading information

Pilot site for grassland carbon trading can be established in Inner Mongolia, first, to build a special platform for grassland carbon auction and trading. Detailed rules and regulations for grassland carbon trading can be instituted and promulgated, based on this platform.

Train professional and technical personnel for carbon trading

It is necessary to establish the special training institutes and organizations for carbon trading professional, along with the construction of environmental trading platform. Meanwhile, the comprehensive management mechanisms should be founded as the scheme for practitioners and professional supervision and management.

Conclusion

Due to gradual degradation, desertification and salinization, the vegetation coverage of grassland has been declining to release significant amount of CO_2, originally sequestered in the soil, into the atmosphere and to reduce grassland yields to seriously affect the development of animal husbandry. Therefore, in order to restore grassland carbon pool and promote regional sustainable development, it is necessary to implement improved and rational grassland governance, firstly. In recent years, China's government has promulgated many corresponding policies, such as returning farmland to grassland, enclosure, banning grazing, deferred grazing, rotational grazing and artificial planting, to realize degraded grassland restoration and to enhance grassland utilizations. Secondly, the principle of livestock-forage balance should be followed, unconditionally, as stipulated in Article 45 of the Grassland Law. For every local government, all necessary

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and effective precautionary measures should be taken, according to regional grassland yields and other conditions, to prevent overgrazing, to achieve dynamic balance between livestock and forage, and to promote harmonic equilibrium between animal husbandry development and grassland ecosystem protection. Thirdly, in order to greatly promote grassland carbon sink, it is essential to establish trading mechanism and market system for grassland carbon sink trading.

References

1. Coupland RT (1979) Grassland ecosystems of the world: Analysis of Grasslands and their Uses. Cambridge University Press, London.
2. Houghton RA (1995) Changes in the storage of terrestrial carbon since 1850. In: Lal R, Kimble JM, Levine E, Stewart BA (Eds.), Soils and Global Change. CRC Press Inc., Boca Raton, Florida, USA.
3. Li L (1998) Effects of land-use change on soil carbon storage in grassland ecosystems. Acta Photogeological Sinica 22(4): 300-302.
4. Conant RT (2010) Challenges and opportunities for carbon sequestration in grassland systems. Food and Agriculture Organization, Fort Collins.
5. Conant RT, Ogle SM, Paul EA, Paustian K (2011) Measuring and monitoring soil organic carbon stocks in agricultural lands for climate mitigation. Frontiers in Ecology and the Environment 9(3): 169-173.
6. Conant RT, Paustian K, Grosso SJD, Parton WJ (2005) Nitrogen pools and fluxes in grassland soils sequestering carbon. Nutrient Cycling in Agroecosystems 71: 239-249.
7. Fissore CJ, Espeleta EA, Nater SE, Hobbie (2010) Limited potential for terrestrial carbon sequestration to offset fossil-fuel emissions in the upper midwestern US. Frontiers in Ecology and the Environment 8(8): 409-413.
8. Liu H, Sun X, Wang J, Yao W, Shi X (2010) Research progress in effects of grassland degradation on regional climate in inner Mongolia region. Journal of Anhui Agricultural Science 38(27): 15161-15163.
9. Liu Q (1999) An inquiry into the ecological economic value of grassland resource in China. Sichuan Grassland 4(1): 1-4.
10. Piao S, Fang J, He J, Xiao Y (2004) Spatial distribution of grassland biomass in China. Acta Photogeological Sinica 28(4): 491-498.
11. Wang Y (2004) A Study on Grassland Degradation and Sustainable Development of Pastoral Livestock Industry in Inner Mongolia. Inner Mongolia Agricultural University, Hohhot, China.
12. IPCC (2006) Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventories.
13. USEIA (2012) World carbon dioxide emissions data by country. US Energy Information Administration, USA.
14. Ma W, Han M, Lin X, Ren Y, Wang Z, et al. (2006) Carbon storage in vegetation of grasslands in inner Mongolia. Journal of Arid Land Resources and Environment 20(3): 192-195.
15. Shi F, Gao Q, Wan Y, Qin X, Jin L (2009) Effects of managements on soil organic carbon of grassland in China. Precultural Science 26(3): 9-15.
16. Badarhu, Zhao H, (2010) Governance policy for degraded grassland in inner Mongolia. Animal Husbandry and Feed Science 31(6-7): 258-261.
17. Baidu (2012) The deterioration standard of native grassland in inner Mongolia, Mongolia.
18. Yang Y, Fang J, Ma W, Smith P, Mohammad A, et al. (2010) Soil carbon stock and its changes in northern China's grasslands from 1980s to 2000s. Global Change Biology 16(11): 3036-3047.

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