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Research Article

Annual Greenhouse Gas Removal Estimates of Grassland Soil in Korea

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ABSTRACT

The study was conducted to determine greenhouse gas (GHG) inventories in grasslands. After 'Low Carbon Green Growth' was declared a national vision on 2008, Medium-term greenhouse gas reduction was anticipated for 30% reduction compared to Business As Usual (BAU) by 2020. To achieve the reduction targets and prepare to enforce emissions trading (2015), national GHG inventories were measured based on the 1996 Intergovernmental Panel on Climate Change Guidelines (IPCC GL). The national Inventory Report (NIR) of Korea is published every year. Grassland sector measurement was officially added in 2014. GHG removal of grassland soil was measured from 1990 to 2012. Grassland area data of Korea was used for farmland area data in the 「Cadastral Statistical Annual Report (1976~2012)」. Annual grassland area corresponding to the soil classification was used 「Soil classification and commentary in Korea (2011)」. Grassland area was divided into 'Grassland remaining Grassland' and 'Land converted to Grassland'. The accumulated variation coefficient was assumed to be the same without time series changes in grassland remaining grassland. Therefore, GHG removal of soil carbon was calculated as zero (0) in grassland remaining grassland. Since the grassland area increases constantly, the grassland soil sinks constantly . However, the land converted to grassland area continued to decrease and GHG removal of soil carbon was reduced. In 2012 (127.35Gg CO_2), this removal decreased by 76% compared to 1990 (535.71 Gg CO_2). GHG sinks are only grasslands and woodlands. The GHG removaled in grasslands was very small, accounting for 0.2% of the total. However, the study provides value by identifying grasslands as GHG sinks along with forests.

(**Key words :** Grassland, GHG, Inventories, Removal, Sink)

Ⅰ. INTRODUCTION

The ecological importance of grasslands has mainly been emphasized in the field of biodiversity. Recently, reports signifies lot of attention to carbon storage in grassland with regard to climate change. Grassland soil carbon stocks amount to at least 10% of the global total (Eswaran et al. 1993), but other sources estimate up to 30% of world soil carbon (Anderson 1991). This concern of grassland is further increased by land use, land use change, and forestry (LULUCF).

The LULUCF sector deals with GHG emissions and removals resulting from land use such as forestry activities and land-use change. The land-use category is divided into six kinds such as forest land, cropland, grassland, wetlands, settlements, other land by Good Practice Guidance (GPG) of IPCC. Although forestry is the most important in terms of carbon storage. which can store large amounts of organic matter in cropland and grassland soil (Post and Kwon, 2000).

In Korea, After 'Low Carbon Green Growth' was declared a national vision on 2008, Medium-term greenhouse gas reduction was anticipated for 30% reduction compared to Business As Usual (BAU) by 2020. To achieve the reduction targets and prepare to enforce emissions trading (2015), national GHG inventories were measured based on the 1996 IPCC GL. Every year, for preparing the national GHG inventory, National Greenhouse Gas Inventories Measurement, Reporting, Verification (MRV) and National Inventory Report (NIR) has been written based on the IPCC 1996 GL, GPG 2000, GPG 2003.

The national GHG inventory details national GHG emissions in energy, industrial processes, agriculture, LULUCF and waste sectors in accordance with IPCC GL. LULUCF sector measure all anthropogenic GHG emissions of managed land. LULUCF is the only sector to measure the emissions and removals. Grasslands belong to the LULUCF sector with forest land, cropland, wetlands,

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settlements, other land. Grassland sector measurement was officially added in 2014.

Ⅱ. MATERIALS AND METHODS

1. Grassland area

Grassland area data of Korea is used farmland area data in cadastral statistical annual report from 1976 to 2012. Annual grassland area of the soil classification are divided into jeju province and other. Except for jeju, the national rate of soil types are LAC soil 94.5%, sandy soil 5.5% (Kang et al, 2011). The nationwide area was calculated according to rate of soil types.

All grassland soil of jeju was regarded as a volcanic ash soil. Grassland area of jeju was estimate farmland area data in cadastral statistical annual report.

Depending on the default inventory storage period of 20 years of the IPCC GL, time series completeness of grassland data does not exist in the Korea (1970~1975) were supplemented through trend extrapolation.

LULUCF divided land use into six purpose categories and computes the change in emissions, according to whether the land uses “maintain” or “change” in purpose. So, this section divides grassland into two subcategories, “Grassland remaining Grassland” and “Land converted to Grassland”, and describes them separately in the following subsections. The grassland remaining grassland area is the smaller area as compared to in the inventory year and 20 years ago. Land converted to grassland is larger than 20 years ago.

Japan classifies its national land into six categories−forest land, cropland, grassland, wetlands, settlements, and other land−and subdivides each of them into two subcategories by distinguishing them on the basis of whether or not land conversion has been occurred, in accordance with the 2006 IPCC GL. It also uses 20 years, a default value in the 2006 IPCC GL, when distinguishing the land conversion (Ministry of the Environment, Japan, 2015)

2. Emissions and removals coefficient

To calculate the Soil Organic Carbon Stocks (SOC) of grassland, it was used that default reference soil organic carbon stocks (SOC_{REF}) provided from IPCC GL according to climate and land type.

Climate of Korea belongs to warm temperate and moist climate. Total soil in Korea except for jeju are classified into low activity clay (LAC) and sandy soils. All grassland soil of jeju was regarded as a volcanic ash soil. Soil type area are LAC: 70.6%, Sandy soil: 4.1, Volcanic ash soil in Jeju: 23.5% (Kang et al., 2011). The amount of SOC was calculated by applying the accumulated variation coefficient of 1.0 and area of soil type.

Accumulated variation coefficient was applied that basic value of GPG-LULUCF depending separated by method of land utilization, tillage methods and organic matter inputs. Accumulated variation coefficient of F_{LU} depending was separated by land utilization. Type of land utilization change is applied that basic value of GPG-LULUCF is 1.0 for the entire grassland and the whole climate system. Accumulated variation coefficient of F_{MG} by grassland management system was applied that 1.0 (continue to be managed without damaging grasslands). Accumulated variation coefficient of F_I by the amount of organic matter utilization was applied 1.0 on the basic amount used in grassland of Korea.

3. Method of measurement

CO_2 emissions and removal of grassland sector in Korea was applied on the basis value of representing the grassland soil conditions in Korea from GPG-LULUCF. Because area of organic soil was too small, organic grasslands were not existed. Carbon stock variation of the land of maintained as grassland was calculated zero (0) in accordance with the

Table 1. Default reference (under native vegetation) Soil Organic Carbon Stocks (SOC_{REF})

(t C / ha, soil depth 0~30 cm)

Climate	LAC Soil	Sandy Soil	Volcanic Soil
Warm Temperate, Moist	63	34	80

ANNUAL CHANGE IN CARBON STOCKS IN SOILS IN GRASSLAND REMAINING GRASSLAND

$$\Delta C_{GG_{Soils}} = \Delta C_{GG_{Mineral}} - \Delta C_{GG_{Organic}} - \Delta C_{GG_{Liming}}$$

$\Delta C_{GG_{Soils}}$: annual change in carbon stocks in soils in grassland remaining grassland, tonnes (t C / yr)

$\Delta C_{GG_{Mineral}}$: annual change in carbon stocks in mineral soils in grassland remaining grassland, tonnes (t C / yr)

$\Delta C_{GG_{Organic}}$: annual change in carbon stocks in organic soils in grassland remaining grassland (t C / yr)

$\Delta C_{GG_{Liming}}$: annual C emissions from lime application to grassland (t C / yr)

organic matter accumulated variation coefficient of the same trial without time series change by land utilization, management system and organic matter utilization.

Ⅲ. RESULTS AND DISCUSSION

Basic data of land use classification uses statistical data such as cadastral statistics, agriculture census. Grassland sector should take advantage of pasture area on the cadastral statistics.

In some cases, estimate the area of land conversion using the fair value ratio, use interpolation and trend extrapolation because lack of statistic data (Ministry of the Environment, Japan, 2015). There is no pasture area from 1970 to 1975 on the cadastral statistics. Therefore, the trend extrapolation method was used from 1970 to 1975. However, the grassland area was reduced sharply during two years (1976 ~1977), it could not calculate from 1970 to 1975. so, 1976 and 1977 was added to the trend extrapolation (Table 2).

According to grassland area statistics, total amount of grassland area is constantly increased (Fig. 1). In 2012, Korea's grassland area was about 58,019 ha. But, increasing rate is gradually reduced. Between 2011 and 2012, decreased from 58,179 ha to 58,019 ha.

Based on the soil maintenance period of 20 years of the IPCC GL and subdivide annual grassland area. As the starting point for each inventory year, the grassland area divides grassland remaining grassland area (Table 3) and land converted to grassland area (Table 4) for 23 years.

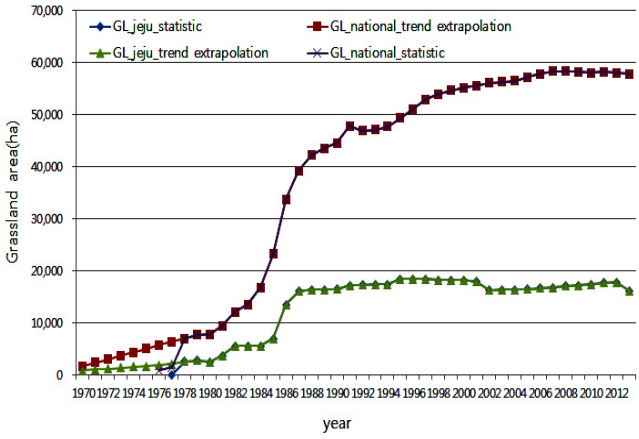

Fig. 1. Grassland area with trend extrapolation.

Grassland remaining grassland is remaining grassland during the past 20 years. it is an area 20 years ago from their inventory year.

Land converted to grassland occurred in the lands that were converted from other land-use categories to grassland within the past 20 years. it was increased area more than 20 years ago. Because of this grassland area increases every year, grassland area replaced by other land can be assumed to be non-existent. But, land converted to grassland area is continuously decreased.

1. Greenhouse gas removal

As the starting point for each inventory year, the

Table 2. Grassland area from 1970 to 1977

Region	Area (ha)							
(year)	1970	1971	1972	1973	1974	1975	1976	1977
National	1,654	2,320	2,985	3,650	4,315	4,981	5,646	6,311
Jeju	805	975	1,146	1,316	1,486	1,657	1,827	1,997

Table 3. Grassland remaining grassland area by soil division

Soil Division (year)	Area (ha)							
	1990	1991	1992	1993	1994	1995	1996	1997
Gross Area	1,654	2,320	2,985	3,650	4,315	4,981	5,646	6,311
LAC	803	1,271	1,739	2,206	2,674	3,142	3,609	4,077
Sand	47	74	101	128	155	182	209	236
Volcanic Ash	805	975	1,146	1,316	1,486	1,657	1,827	1,997
Soil division (year)	Area(ha)							
	1998	1999	2000	2001	2002	2003	2004	2005
Gross area	6,976	7,641	7,744	9,407	12,021	13,442	16,733	23,218
LAC	4,172	4,629	4,989	5,436	6,194	7,503	10,592	15,450
Sand	242	268	289	315	359	435	614	895
Volcanic Ash	2,562	2,744	2,466	3,657	5,468	5,505	5,527	6,873
Soil division (year)	Area (ha)							
	2006	2007	2008	2009	2010	2011	2012	
Gross Area	33,701	39,261	42,217	43,486	44,517	47,855	46,848	
LAC	19,175	21,949	24,493	25,656	26,581	28,993	27,937	
Sand	1,111	1,272	1,420	1,487	1,541	1,680	1,619	
Volcanic Ash	13,414	16,040	16,304	16,343	16,396	17,181	17,292	

Table 4. Land converted to grassland area by soil division

Soil Division (year)	Area (ha)							
	1990	1991	1992	1993	1994	1995	1996	1997
Gross Area	42,863	45,535	43,863	43,418	43,350	44,315	45,469	46,571
LAC	25,778	27,722	26,198	25,920	25,973	26,083	27,345	28,577
Sand	1,494	1,607	1,518	1,502	1,505	1,512	1,585	1,656
Volcanic Ash	15,591	16,206	16,147	15,996	15,872	16,721	16,539	16,338
Soil Division (year)	Area (ha)							
	1998	1999	2000	2001	2002	2003	2004	2005
Gross Area	46,947	46,964	47,433	46,214	44,036	42,852	39,782	33,983
LAC	29,599	29,837	30,035	30,269	31,443	30,258	27,365	23,055
Sand	1,715	1,729	1,741	1,754	1,822	1,754	1,586	1,336
Volcanic Ash	15,632	15,398	15,657	14,191	10,771	10,841	10,831	9,592
Soil Division (year)	Area (ha)							
	2006	2007	2008	2009	2010	2011	2012	
Gross Area	24,113	19,069	16,118	14,778	13,538	10,324	11,171	
LAC	19,736	17,353	14,512	13,188	11,924	9,354	10,121	
Sand	1,144	1,006	841	764	691	542	587	
Volcanic Ash	3,233	710	765	826	924	428	463	

Table 5. The greenhouse gas removal from 1990 to 2012 in grassland sector

Soil division (year)	Removal (thousand tons of CO_2eq)							
	1990	1991	1992	1993	1994	1995	1996	1997
Remaining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Converted	-535.71	-567.90	-548.87	-543.35	-542.16	-555.91	-568.28	-580.01
Total	-535.71	-567.90	-548.87	-543.35	-542.16	-555.91	-568.28	-580.01
Soil Division (year)	Removal (thousand tons of CO_2eq)							
	1998	1999	2000	2001	2002	2003	2004	2005
Remaining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Converted	-581.84	-581.23	-587.40	-568.68	-532.49	-519.41	-484.80	-415.29
Total	-581.84	-581.23	-587.40	-568.68	-532.49	-519.41	-484.80	-415.29
Soil Division (year)	Removal (thousand tons of CO_2eq)							
	2006	2007	2008	2009	2010	2011	2012	
Remaining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Converted	-282.50	-217.12	-184.08	-169.20	-155.57	-117.70	-127.35	
Total	-282.50	-217.12	-184.08	-169.20	-155.57	-117.70	-127.35	

grassland area was divided into grassland remaining grassland area and land converted to grassland area for 23 years.

Accumulated variation coefficient was assumed to be the same without time series change in grassland remaining grassland. Therefore, GHG removal of soil carbon was calculated as zero (0) in grassland remaining grassland.

The grassland soil was sinks with constantly increasing of grassland area. But, land converted to grassland area constantly decreased and GHG removal of soil carbon was reduced. In 2012 (127.35 Gg CO_2eq), this removal decreased 76% than in 1990 (535.71 Gg CO_2eq). Total GHG removal in Korea were 50,937 Gg CO_2eq in 2012. GHG removal of grassland sector was very small, accounted for 0.2% of the total (Ministry of the Environment, 2014). However, the study provides value by identifying grasslands as GHG sinks along with forests.

Ⅳ. CONCLUSION

This study provide GHG removal from 1990 to 2012 in grassland. This section divides grassland into two subcategories, “Grassland remaining Grassland” and “Land converted to Grassland”, and describes them separately in the following subsections. The grassland soil was sinks with constantly increasing of grassland area. GHG removal was reduced because land converted to grassland constantly decreased. But, GHG sinks are only grasslands and woodlands. It is important that grassland has been identified as a new GHG sinks with forests.

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