B-2.4.2 Emission of Trace Gases Contributing Greenhouse Effect from Grassland

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Abstract We measured the fluxes of for methane (CH_4) and nitrous oxide (N_2O) in grassland in relation to fertilization and influences of animal excreta. Grassland showed the function as a sink for atmospheric CH_4, and N_2O emission through the year. The fluxes of CH_4 uptake and N_2O emission were calculated for forest-floor, unfertilized and fertilized grasslands as 449.5, 106.8 and 100.0 CH_4-C mg/m^2/yr, 45.9, 47.4 and 190.1 N_2O-N mg/m^2/yr, respectively. Surface application of cattle slurry or fresh feces to grassland resulted remarkable emission of CH_4 and N_2O. The emission of CH_4 decreased remarkably by injecting. Cattle slurry into the soil (about 15cm of depth) with nitrification inhibitor (thiourea, at rate of 0.5% slurry-N) restrained release of CH_4 and N_2O remarkably. However, the N_2O emission was still larger than the case of cattle slurry applied to the surface soil without the nitrification inhibitor.
Then, we estimated of the size of source or sink for CH_4 and N_2O of grassland in the world and Japan. The uptakes of atmosphere CH_4 by grassland were estimated as 3,586 and 0.8 CH_4-C Gg/yr in the World and Japan, respectively. The amounts of N_2O emission from grassland were estimated as 1,979 and 1.2 N_2O-N Gg/yr in the world and Japan, respectively. Additional emissions of N_2O and CH_4 from livestock manure that reduced to grassland were estimated as 189 N_2O-N Gg/yr and 1,626 CH_4-C Gg/yr in the World, 14 N_2O-N Mg/yr and 116 CH_4-C Mg/yr in Japan, respectively.

Key Words Grassland, Nitrous oxide, Methane, Greenhouse gas, Animal excreta

1. Introduction

Methane (CH_4) and nitrous oxide (N_2O) are long-lived radiatively active trace gases that account for ~ 20% of the total anticipated greenhouse effect. It has been suggested that agricultural productions contribute to the increases of atmospheric concentration of CH_4 and N_2O. Grassland is important agricultural land. But diversity in management of fertilization or cultivation and uneven impacts of animal excreta in pasture, which prevailing in grassland, complicate the quantitative evaluation for emission of CH_4 and N_2O from grassland.

2. Research Objective

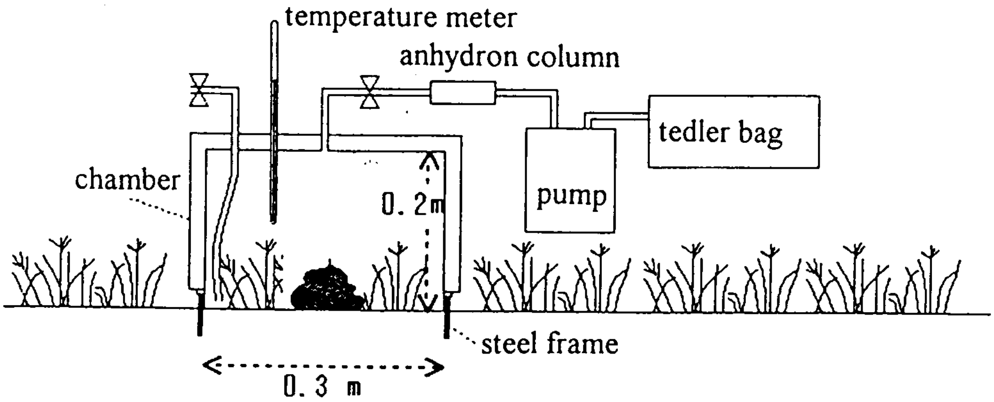
We estimate the size of source or sink for CH_4 and N_2O in grassland basing on the measurements of the fluxes of both gases in relation to fertilization, impacts of animal excreta, effects of vegetation in grassland and other environmental conditions affecting the fluxes.
Then, We estimate the amount of CH_4 and N_2O from grassland and pasture in the world and Japan.

3. Research Method

(1) Measurement method of gas flux
Grassland for gas sampling sites placed at National Grassland Research Institute, in Nishinasuno, Tochigi, Japan. The grassland soil is brown lowland soil containing volcanic ash in the surface layer. We established triplet microplots for each experimental sites by enclosing with open-ended

steel frames (0.3m×0.3m). Flux measurement method was closed chamber method. Chamber height was 0.2m (Figure 1). Each gas sampling was commenced about from 8:00A.M. to 10:00A.M.. After chamber setting, gas samples were taken from the inside chamber into tedlar bag at 0, 15, 30 minutes. CH_4 and N_2O concentration measured by FID-GC, ECD-GC, respectively.

Figure 1. Outline of gas sampling



(2) Estimations of CH_4 and N_2O emissions from grassland in Japan and the World

Estimations of CH_4 and N_2O emissions from grassland in Japan and World were calculated from following factors:

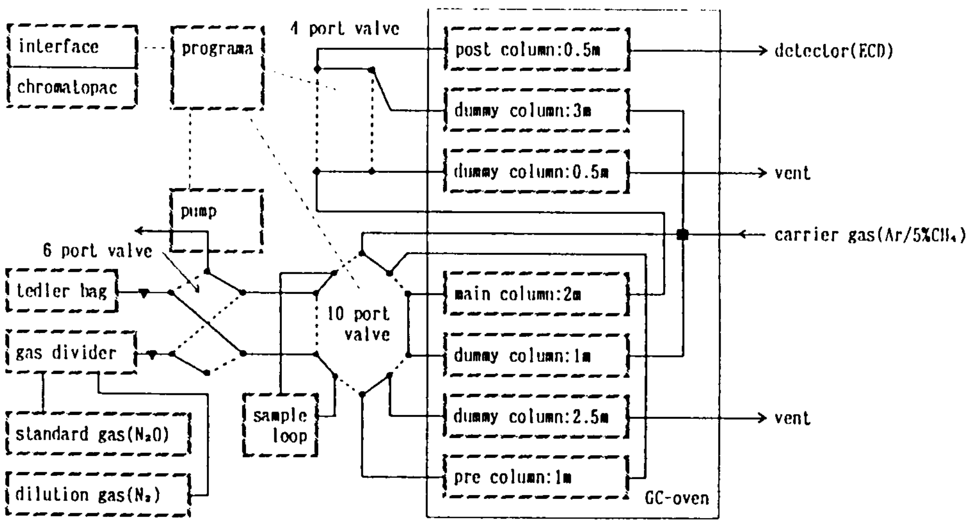
- our experimental rates
- the assessment by the Model describing the growth of grazing cattle (Tsuiki et al. 1990)
- the statistics price from FAO yearbook and the statistics by Division of Animal Industry, MAFF, Japan

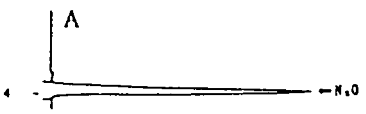
4. Result and Discussion

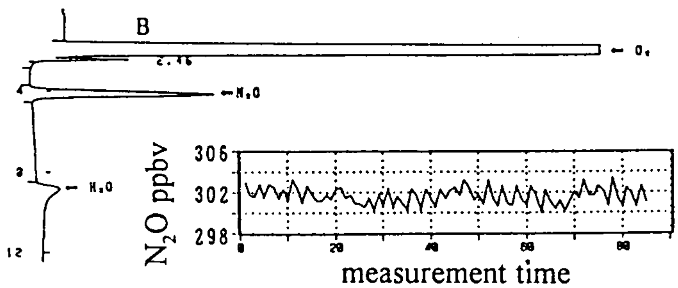
(1) The improvement of GC circulation for N_2O measurement

Low level of N_2O efflux from unfertilized grassland required some improvement of accuracy in the analysis of atmospheric N_2O. We attained rapid and accurate analysis by removing oxygen and water in air sample with pre-cutting and back-flushing system combined to ECD-GC (Figure 2). N_2O measurement method with this improvement can analyzed stability and analysis time of 5 minutes for 1 sample.

Figure 2. Outline of GC-circulation and chromatogram







measurement time

gas chromatogram of atomosphire
A : with pre-cutting and back-flashing system
B : without pre-cutting and back-flashing system

N_2O content change at rpitation analysis of atomosphire in lab.

detector : ECD(1nA, 348℃) column : Porapak Q(70℃, 3.5m) carrier gas : Ar/$CH_4$5%, 25ml/min. sample : 5ml

(2) Measurement of CH_4 and N_2O fluxes of grassland

CH_4 and N_2O flux measurements in established grasslands (fertilized and unfertilized sites dominated by orchardgrass) and neighboring forest -floor (dominated by Red-Pine) were carried out once in every week(measurements after fertilization were carried out every day until N_2O flux start to decrease) for one year from 1,May,1991 to 5, May, 1992. Every fertilization after cutting(5 times annually) were done with N-P_2O_5-K_2O =5-5-5 g/m^2.

Both grasslands and forest-floor have the function as sink for atmospheric CH_4, through the year. On the other hand, both grasslands and forest-floor showed N_2O emission through the year (Figure 3).

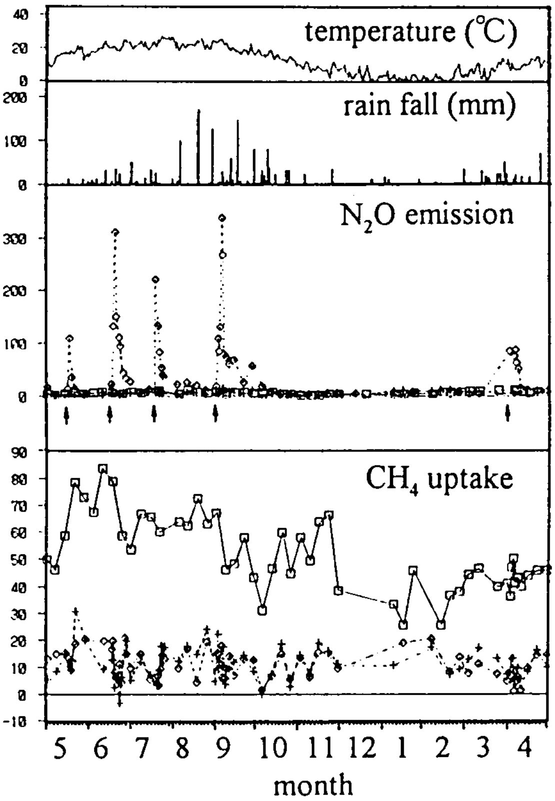


Figure 3. CH_4 and N_2O flux of grassland and forest-floor
□: forest-floor +: unfertilized grassland
◇: fertilized grassland
unit : CH_4-C or N_2O-N ug/m^2/hr
measurement span: 91/05/01~92/05/01
↑ : fertilizer application
(N-P_2O_5-K_2O=5-5-5 g/m^2)

Annual gas-fluxes were estimated by our measurement (Table 1).

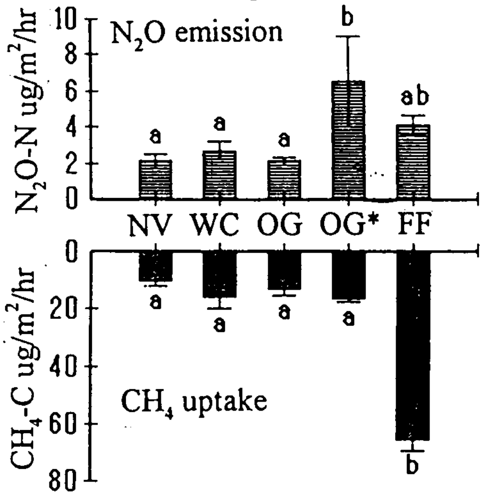
Table1. Annual CH_4 and N_2O flux from grassland and forest-floor

	CH_4 uptake	N_2O emission
forest-floor	449.5	45.9
unfertilized grassland	106.8	47.4
fertilized grassland	100.0	190.1

unit : CH_4-C or N_2O-N ug/m^2/hr measurement span : 1991/05/01~1992/05/05

Fertilized grassland showed higher rate of N_2O efflux than in unfertilized one, especially much N_2O (0.2～1.0% of applied N) was evolved after the fertilizer application. Then, annual averaged CH_4 uptake rate was 11 CH_4-C ug/m^2/hr, independently with fertilization or vegetation. Annual averaged N_2O efflux from unfertilized grassland and forest-floor was 5 N_2O-N ug/m^2/hr, independently with vegetation (Figure 4).

Figure 4. Gas fluxes of vegetation difference sites



NV : no vegetation
WC : dominated white clobber site
OG : dominated orchardgrass
OG*: dominated orchardgrass(fertilized)
FF : forest-floor
Each sites unfertilized, except OG*
These factors are significant between different mark.
measurement span : 91/05/01～10/01

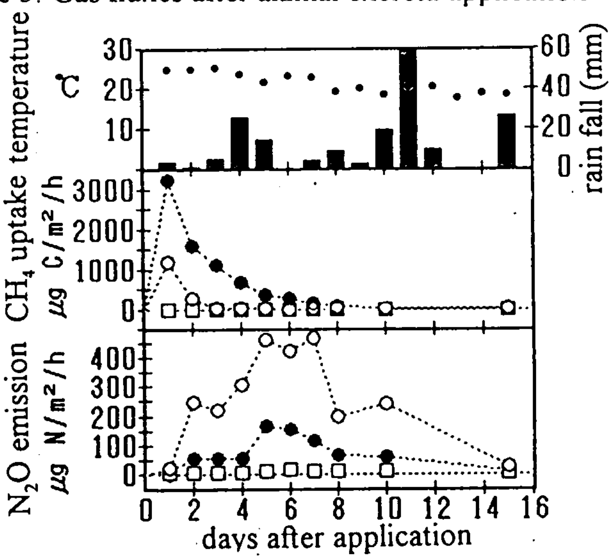
On pasture, CH_4 uptake and N_2O emission were showed. On the other hand, water drinking point of pasture showed CH_4 and N_2O emission (Table 2).

Table 2. CH_4 and N_2O flux on pasture

	CH_4 uptake		N_2O emission	
	grazing area	water drinking point	grazing area	water drinking point
average	12.2	-4.0	25.7	37.0
largest	5.3	-1.5	29.4	14.1
smallest	18.3	-8.3	43.5	53.2

unit : CH_4-C or N_2O-N ug/m^2/yr measurement span : 92/09/21～09/25 (water drinking point : 09/22～09/25)

Figure 5. Gas fluxes after animal excreta application



application amount (g/0.09m^2)
fresh cattle feces : 500g
cattle slurry : 300g

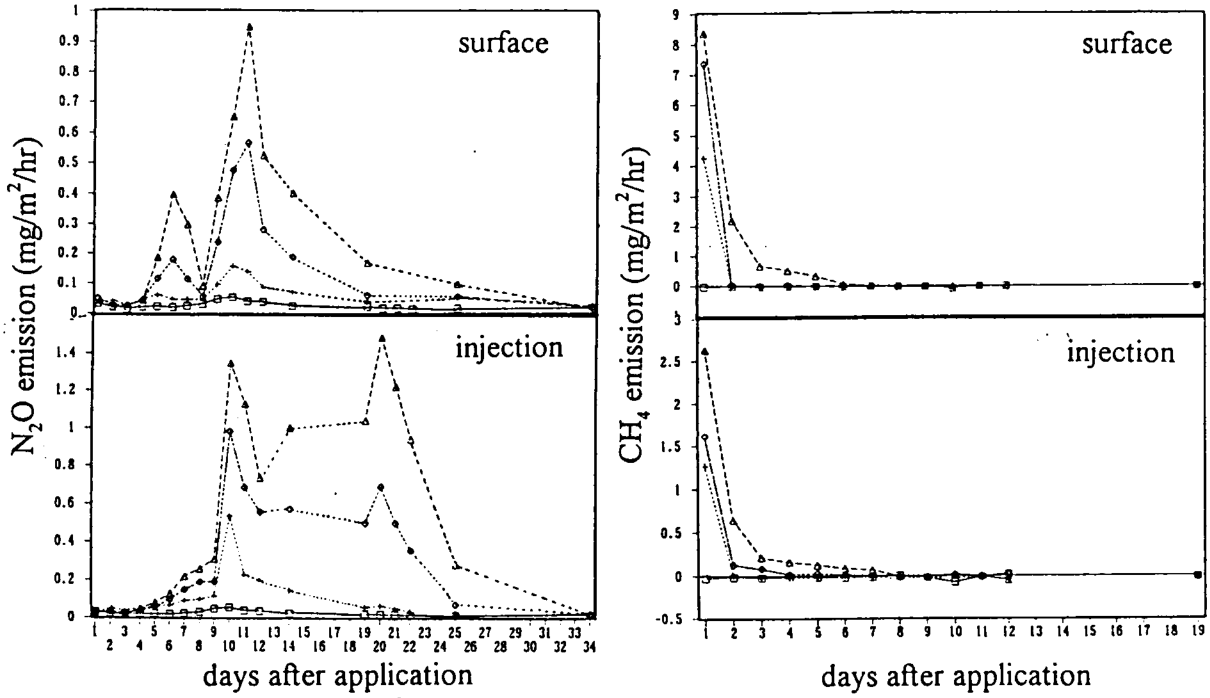
●: fresh cattle feces
○: cattle slurry
□: unfertilized grassland

(3) Measurement of CH_4 and N_2O fluxes from animal excreta

Surface-applied fresh feces and cattle slurry evolved much CH_4 and N_2O (Figure 5).This suggests that animal excreta acts important role as a source of CH_4 and N_2O in grassland.

Cattle slurry application increased CH_4 and N_2O release remarkably. As compared with cattle slurry injection to soil (15cm of depth), cattle slurry surface application showed 3-4 times of CH_4 efflux, 1/2-1/3 times of N_2O efflux. However, CH_4 and N_2O emission rate from applied C and N were not related with fertilized cattle slurry quantity (Figure 6, Table 3). We thought about that this restraint of CH_4 efflux originated from covered by soil, more CH_4 uptake by increase of touch area between soil and cattle slurry. And then, we thought about that this increase of N_2O efflux originated from increased N in the soil by restraint of emitted NH_3 with covered by soil.

Figure 6. Gas fluxes after cattle slurry application



□: no application +: 2t/10a ◇: 6t/10a △: 12t/10a

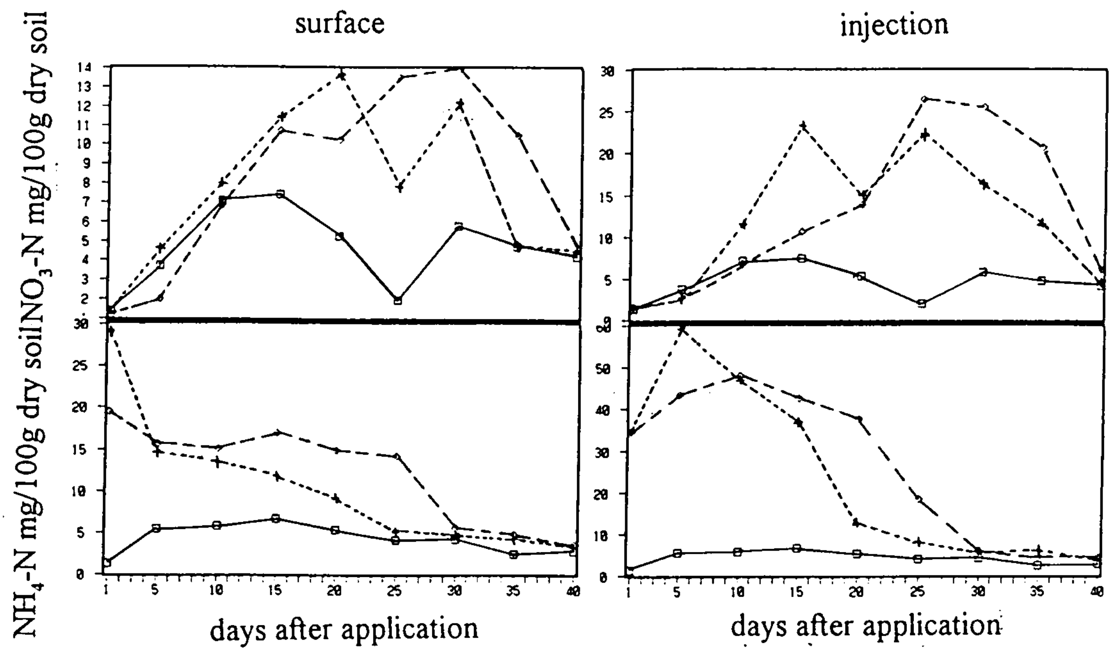
Table 3. The amount of CH_4 and N_2O emission and the rate against total C and N after cattle slurry application

position	amount (t/10a)	N amount added (g-N/m²)	N_2O evolved (mg-N/m²)	N_2O/T-N ratio (%)	C amount added (g-C/m²)	CH_4 evolved (mg-C/m²)	CH_4/T-C ratio (%)
surface	2	11	39	0.35	96	103	0.11
	6	33	85	0.26	289	177	0.06
	12	66	155	0.23	578	291	0.05
injection	2	11	67	0.61	96	30	0.03
	6	33	222	0.67	289	44	0.02
	12	66	425	0.64	578	93	0.02

cattle slurry composition (T-C:4.82%, T-N:0.55%,NH_4-N:0.30%) measurement span : 93/06/11~07/14

The application method of cattle slurry added nitrification inhibitor (thiourea, volume: 0.5% of total-N) injection (about 15cm of depth) restrained release of CH_4 and N_2O remarkably. One of the reasons for restraint of N_2O release was thought that the nitrification of NH_4-N in the cattle slurry was restrained by the nitrification inhibitor. However, in the case of cattle slurry application into the soil with the nitrification inhibitor, N_2O emission occurred more than the case of cattle slurry surface application without the nitrification inhibitor (Figure 7, Table 4).

Figure 7. Soil NH_4-N and NO_3-N content (0-15cm), after cattle slurry application



□: no application +: without nitrification inhibiter ◇: with nitrification inhibitor

Table 4. The amount of CH_4 and N_2O emission and the ratio against total C and N after cattle slurry added nitrification inhibitor application

position		N_2O evolved (mg-N/m^2)	N_2O/T-N ratio (%)	CH_4 evolved (mg-C/m^2)	CH_4/T-C ratio (%)
surface	no-added	36	0.12	480	0.21
	added	21	0.07	456	0.20
injection	no-added	171	0.56	162	0.07
	added	62	0.20	143	0.06

cattle slurry composition (T-C:3.78%, T-N:0.51%, NH4-N:0.28%) applied amount : 6t/10a
measurement span : 94/06/06～07/10

(4) Estimations of CH_4 and N_2O emissions from grassland in japan and world.

We settled the estimation of CH_4 and N_2O flux range from grassland by our measurement results (Table 5).

And then, we decided the size of CH_4 and N_2O source related grassland from FAO yearbook (1992) and the statistics by Division of Animal Industry, MAFF, Japan (Table 6).

Table 5. Emission unit of CH_4 and N_2O related grassland, forest-floor and animal excreta

	median (range)	unit
N_2O		
grassland	47.4 (22.1～72.7)	N_2O-N mg/m^2/yr
nitrogen fertilizer	0.6 (0.2～1.0)	N_2O-N % /N applied amount
feces of grazing cattle	0.06 (0.01～0.11)	N_2O-N %/T-N
urine of grazing cattle	0.37 (0.11～0.62)	N_2O-N %/T-N
cattle slurry	0.18 (0.09～0.26)	N_2O-N %/T-N
excreta of grazing cattle	0.32 (0.09～0.55)	N_2O-N g/cattle/day
forest-floor	45.9 (22.7～69.1)	N_2O-N mg/m^2/yr
CH_4		
grassland	-106.8 (-56.6～-157.0)	CH_4-C mg/m^2/yr
feces of grazing cattle	0.20 (0.09～0.30)	CH_4-C %/T-C
cattle slurry	0.14 (0.06～0.21)	CH_4-C %T-C
excreta of cattle slurry	2.75 (0.85～4.65)	CH_4-C g/cattle/day
forest-floor	-449.5 (-330.2～-568.8)	CH_4-C mg/m^2/yr

Table 6. The size of CH_4 and N_2O source related grassland in the World and Japan

Japan	
area of grassland (except pasture)	344×10^3 ha
area of pasture	375×10^3 ha=305×10^3 ha + 70×10^3 ha (natural)
number of grazing cattle	220×10^3 (cow : 126×10^3, meat : 94×10^3)
World	
total area of grassland	$3{,}357{,}520\times10^3$ ha
grassland area of developed countries	$1{,}188{,}229\times10^3$ ha
grassland area of developing countries	$2{,}169{,}291\times10^3$ ha
livestock number related grassland	
cattle	$1{,}284{,}488\times10^3$
buffalo	$147{,}520\times10^3$
sheep	$1{,}138{,}363\times10^3$
goat	$574{,}181\times10^3$
camel	$17{,}019\times10^3$

Then, we estimated the amount of CH_4 and N_2O emission of grassland in the World and Japan (Table 7). Before estimating, we presumed the following:

- Grassland (except pasture) and pasture in Japan is fertilized N amount 250 kg-N/ha/yr, 54 kg-N/ha/yr, respectively. Natural pasture is not fertilized.
- Grassland of developed countries is fertilized N amount 54kg-N/ha/yr. Grassland of developing countries is not fertilized.
- Emission unit of cattle, buffalo and camel corresponds with one of grazing cattle.
- Emission units of sheep and goat correspond with 1/10 times one of grazing cattle, because

sheep and goat body weight correspond with 1/10 times grazing cattle one.
- Grazing span is 191 day (from the end of April to October) in Japan, 365 day in the world.
- The number of grazing cattle in Japan is one of use in Public pasture.

Table 7. Estimation of CH_4 and N_2O emission in the World and Japan

			Emission unit	Size	Emission
Japan					
grassland (except pasture)		N_2O	47.4×10^4 N_2O-N mg/ha/yr	344×10^3 ha	0.2 Gg/yr
		CH_4	-106.8×10^4 CH_4-C mg/ha/yr	〃	-0.4 Gg/yr
	N fertilizer	N_2O	$0.6/100\times250$ N_2O-N kg/ha/yr	〃	0.5 Gg/yr
pasture		N_2O	47.4×10^4 N_2O-N mg/ha/yr	375×10^3 ha	0.2 Gg/yr
		CH_4	-106.8×10^4 CH_4-C mg/ha/yr	〃	-0.4 Gg/yr
	N fertilizer	N_2O	$0.6/100\times54$ N_2O-N kg/ha/yr	305×10^7 ha	0.1 Gg/yr
grazing cattle	excreta	N_2O	0.32 N_2O-N g/cattle/day	220×10^3 cattle $\times$ 191 day	0.01 Gg/yr
		CH_4	2.75 CH_4-C g/cattle/day	〃	0.1 Gg/yr
World					
grassland (developed country)		N_2O	47.4×10^4 N_2O-N mg/ha/yr	119×10^7ha	563 Gg/yr
		CH_4	-106.8×10^4 CH_4-C mg/ha/yr	〃	-1269 Gg/yr
	N fertilizer	N_2O	$0.6/100\times54$ N_2O-N kg/ha/yr	〃	388 Gg/yr
grassland (developing country)		N_2O	47.4×10^4 N_2O-N mg/ha/yr	217×10^7 ha	1028 Gg/yr
		CH_4	-106.8×10^4 CH_4-C mg/ha/yr	〃	-2317Gg/yr
cattle+buffalo	excreta	N_2O	0.32 N_2O-N g/cattle/day	143×10^7 cattle $\times$ 365day	167 Gg/yr
		CH_4	2.75 CH_4-C g/cattle/day	〃	1437 Gg/yr
sheep	excreta	N_2O	0.32/10 N_2O-N g/sheep/day	114×10^7 sheep $\times$ 365day	13 Gg/yr
		CH_4	2.75/10 CH_4-C g/sheep/day	〃	114 Gg/yr
goat	excreta	N_2O	0.32/10 N_2O-N g/goat/day	57×10^7 goat $\times$ 365day	7 Gg/yr
		CH_4	2.75/10 CH_4-C g/goat/day	〃	58 Gg/yr
camel	excreta	N_2O	0.32 N_2O-N g/camel/day	2×10^7 camel $\times$ 365day	2 Gg/yr
		CH_4	2.75 CH_4-C g/camel/day	〃	17 Gg/yr

The amount of CH_4 uptake of grassland is annually estimated 3,586, 0.8 CH_4-C Gg/yr in the world and Japan, respectively.
On the other hand, the amount of N_2O emission of grassland is annually estimated 1,979, 1.2 N2O-N Gg/yr in the world and Japan, respectively. The amount of N_2O and CH_4 emission from animal excreta in grassland is annually estimated 189 N_2O-N and 1,626 CH_4-C Gg/yr in the world, 14 N_2O-N and 116 CH_4-C Mg/yr in Japan, respectively.
However, this estimation is only calculated by use of emission units in Japan. It is necessary that more accuracy emission units are much studied.