

Burning Biomass in Mongolia

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Abstract

In 1996, the National Remote Sensing Center (NRSC) began using NOAA – AVHRR data for fire monitoring in Mongolia. It expanded its detection technology with the addition of TERRA and AQUA MODIS data, giving it a spatial resolution of 250 m as of 2008, and developed a related methodology and technology for detection and monitoring of active fires and mapping of burned areas over Mongolia.

Additionally, a geodatabase of existing thematic maps with scale of 1:1 million has been established and those maps can be used for integrated analysis with remotely sensed products in order to generate new outcomes as burned biomass in pastoral areas of Mongolia.

This paper discusses remote sensing and GIS analysis of burned areas, calculation of burned biomass over Mongolian pasture lands and integration of results of comparison with some fire emission components.

Key words: correlation, fire emission, fire monitoring, pasture biomass

1. Introduction

The economic and social-specific features of Mongolian nature and geography account for this country's considerable vulnerability to natural disasters. Mongolia has a typical continental climate, with hot summers (temperatures of up to 41°C) and cold winters (temperatures to –53°C). Rainfall is relatively scant varying from 50 mm in the southern desert region, to 450 mm in mountainous areas, with 80%-96% falling in the warm period from May to September. In spring (March-May), due to the severe dry climate, the wind can cause a quick spread of fires once initiated in both forest and open steppe zones.

Forest and steppe fires most frequently occur in Mongolia among Asian countries, due to its lower humidity, dry climate and strong winds in the driest seasons (Fig. 1). According to scholarly surveys, 55.6% of the country's total area is located in a zone exposed to forest and grassland fires and a considerable fraction (98.5%) of the country's forested territories are in a zone assessed as of highest fire risk. About 95% of forest and steppe fires in Mongolia are caused by human activities.

Remote sensing and Geographic Information System (GIS) techniques help in detection of active fires and estimation of burned area, as well as geo-statistical analysis.

Pasture types and their biomass amounts were mapped in the early 2000s. In the present study, we have analyzed the burned areas by integrating, using the map we obtained, and tried to estimate the burned biomass.

2. Data Sets and Methodology

Our forest and steppe fire detection methodology using NOAA-Advanced Very High Resolution Radiometer (AVHRR) data was developed in 1996 at the National Remote Sensing Center (NRSC) and the methodologies were upgraded and applied to Moderate resolution Imager Spectroradiometer (MODIS) data by timing.

Each of the TERRA and AQUA satellites with MODIS sensors covers the Mongolian territory twice daily. The MODIS sensor has 36 channels with 250 m, 500 m and 1 km spatial resolution and generates some standard products such as cloud cover, Normalized Difference Vegetation Index (NDVI), snow and fire hot spots which are available to the user community. The fire products are generated based on the temperature anomaly values.

The statistical data on the number of fire occurrences and burned area from 1963 to 2010 were analyzed for estimation of fire risk zones and fire occurrence trends and analyzed over five year periods.

A digital pasture map was used for burned biomass calculation from 1996 to 2010.

2.1 Active fire detection

Active fires are determined on the basis of thermal band information and ground reflectance values of both satellites' data.

In the NOAA-AVHRR imagery the fire spots are mostly identified by different band combinations and also temperature values.

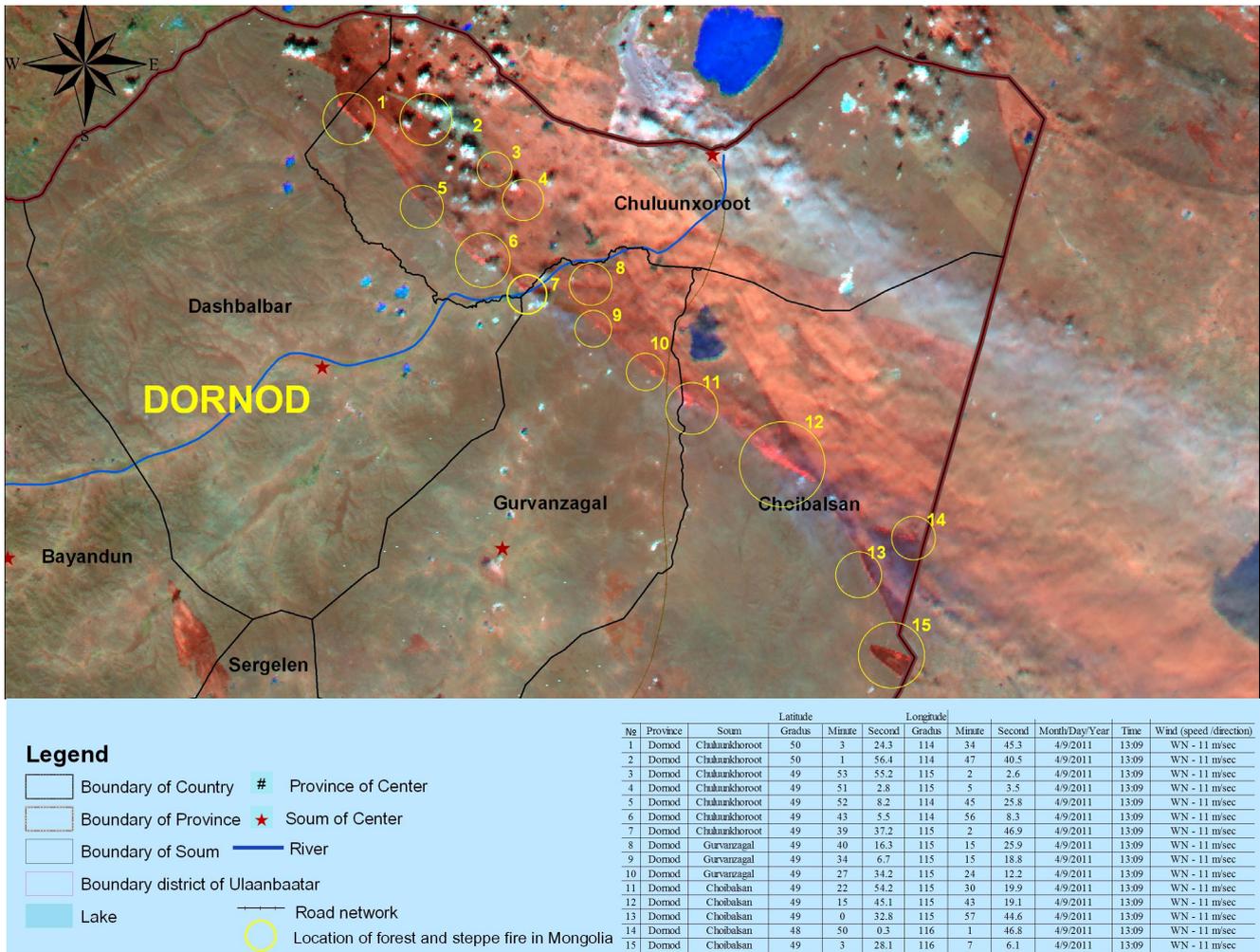


Fig. 1 A map showing forest and steppe fires. (9 April 2011, Terra and Aqua MODIS data, produced by Information and Computer Center National Remote Sensing Center, NAMEM of the Ministry for Nature, Environment and Tourism.)

The fire product from the MODIS data consists of two different parts; one is the hot spot geographic location file and the other is red dots extracted from raw imagery at 1 km spatial resolution. At the NRSC, we are still working on the checking and validation procedure for the hot spots and on fire map generation at 250 m resolution.

2.2 Burned area calculation

After the spring and autumn forest and steppe fires stop completely, we produce a map of the burned area for the whole territory of Mongolia. Our main method for mapping the burned area has been an unsupervised classification method with simple digitizing techniques for calculating the burned area, using image processing and GIS software.

In real time, we generate value added fire maps with a rough estimation of the active fire area, such as the width and length of the burning area in terms of kilometers. The MODIS-data-based calculation of the burned area is estimated to be 16 times better than that using National Oceanic and Atmospheric Administration (NOAA) satellite data.

2.3 Burned biomass estimation

A pasture (hay) map of Mongolia was developed in the early 2000s and it indicates the biomass amount of each pasture type. We extracted the yearly burned biomass amount from this map for the period of 1996 to 2010.

3. Results

3.1 Fire detection

Since the establishment of a NOAA satellite receiving station at the NRSC of Mongolia in 1987, the staff of the Center has developed and tested technologies for monitoring natural disasters, such as forest and steppe fires, droughts, floods, meteorological phenomena, etc.

The recent fire danger situation in forest and steppe zones has challenged the staff of the NRSC to test and improve their operational technology so as to process and transfer fire location and other data quickly to disaster-related and administrative organizations. In the last three years, 788 fires have been detected primarily by satellite data, thus saving millions of dollars. The accuracy of detected hot spots as fires is estimated to be 78.9% of the total number of cases between 1996 and 2009.

3.2 Burned area maps

Since 1986 we have mapped burned areas twice a year, for spring and autumn. From that, we have mapped the total burned area of whole country (Erdenesaikhan and Erdenetuya, 1999). After 2007, 250 m MODIS data were used, improving the accuracy of the burned area map.

Figure 2 shows the size of burned forest and steppe areas and Fig. 3 shows the burned area map for 1997, overlapped with the pasture map of Mongolia which was used in estimating the burned biomass.

3.3 Fire occurrence statistics

The probability of occurrences of fire in the country's forests and steppe areas substantially increases in the dry periods of spring and autumn. Over 60% of the forest fires are recorded to take place during a period from April to May, with 65.5% breaking out in the afternoon, between 12.00 and 16.00 hours.

Although in most cases fire occurrences are triggered by human actions (93.6%), there are also natural factors leading to fire occurrences. In other words, at times when

the weather is dry, there is plenty of inflammable material in the forest and wind speeds are higher, all these factors provide favorable preconditions for fire occurrences. The probability of forest fire occurrences decreases to very insignificant when the amount of precipitation exceeds 2.0 mm. Fires raging in arid pastures are often associated with strong winds. On April 11, 1996, a violent wind rampaged through the territories of the eastern *aimags* (provinces), a fierce steppe fire covering 711,000 hectares of Dornod Aimag's seven *soums* (sub provinces) killed 33,700 head of cattle, destroyed over 160 pens and 90 gers, causing damages estimated at MNT10.6 million (Mongolian tugrugs) (April 2006 value: ca. \$US 10,000), and killing or injuring fourteen people. According to recent statistics, 50-60 forest fires and 80-100 grassland fires are recorded in Mongolia every year (Wingard *et al.*, 1998 and updated).

The number of fire occurrences and the area affected by fires were analyzed for five-year periods and are shown in Table 1. Winters and springs from 1996 to 1998 were extremely dry, with snow lacking in most areas.

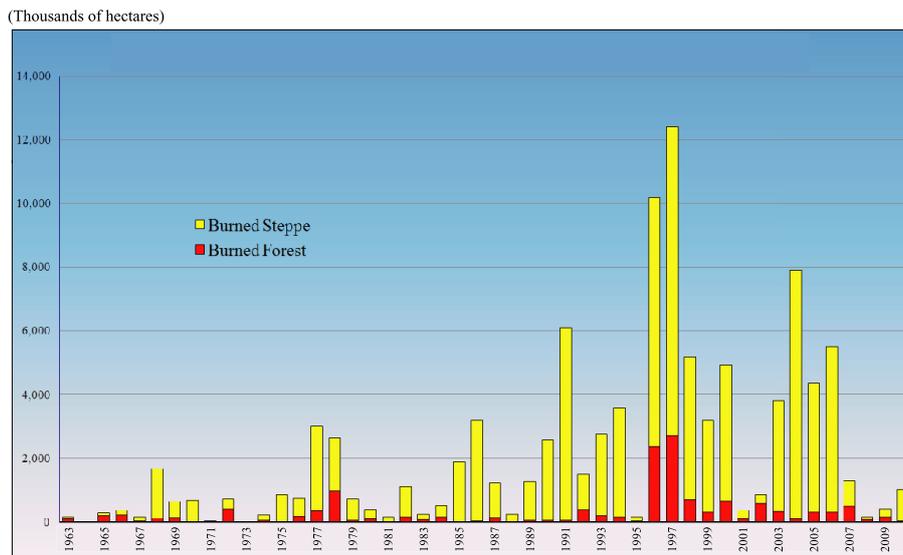
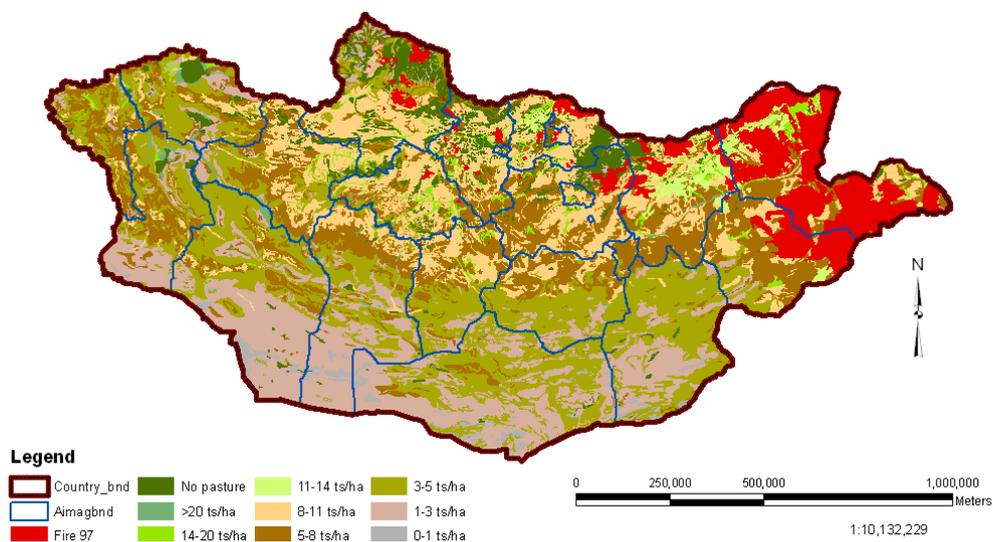


Fig. 2 The burned forest and steppe area, 1963 - 2010.



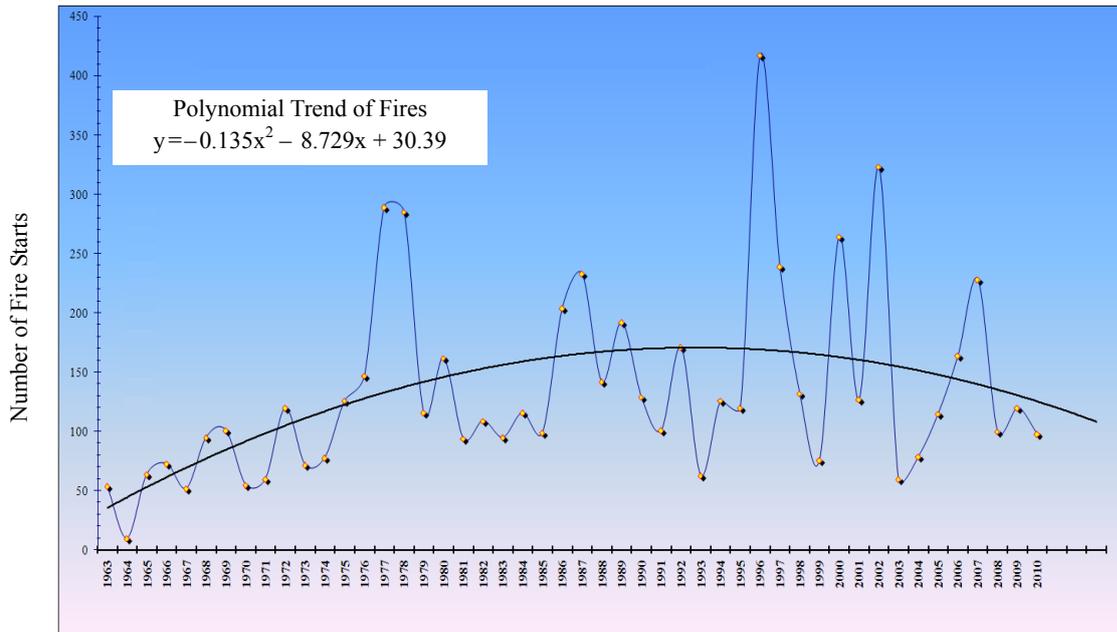


Fig. 4 Number of fires occurring from 1963 to 2010.

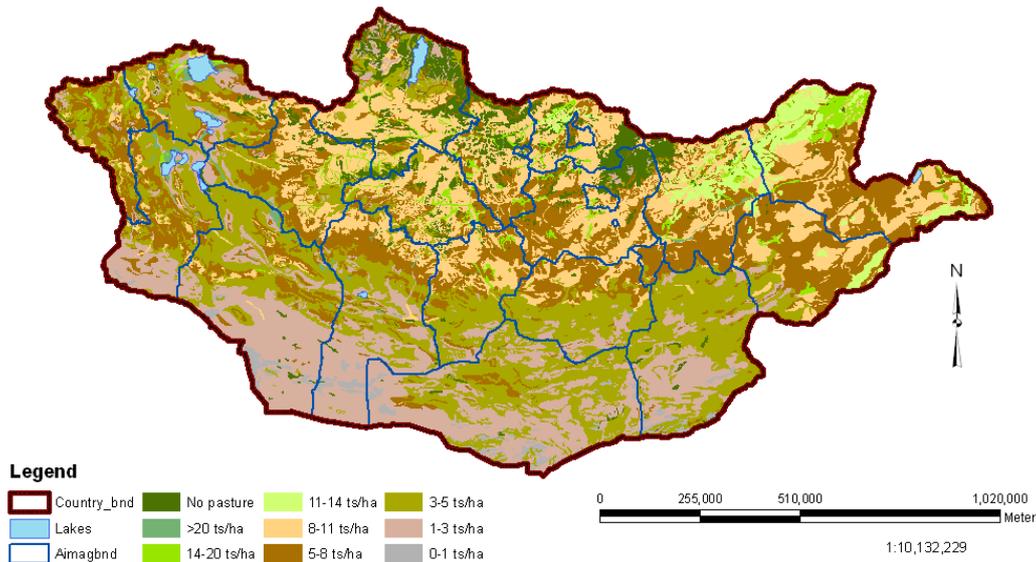


Fig. 5 Pasture biomass map of Mongolia.

Table 1 Number of fires and area destroyed by fire (thousands of hectares).

Period	Number of fires	Total burned area (thousands of hectares)	Average hectares burned per fire event
1966 – 1970	376	3520.3	9.4
1971 – 1975	456	1856.6	4.1
1976 – 1980	999	7529.0	7.5
1981 – 1985	513	3925.2	7.7
1986 – 1990	900	8516.0	9.5
1991 – 1995	581	14144.6	24.3
1996 – 2000	1128	35979.4	31.9
2001 – 2005	704	17205.6	24.4
2006 – 2010	710	8388.6	11.8

From late February to early June of these years, Mongolia suffered from large-scale forest and steppe fires that devastated large parts of the country. During these fire episodes 29 people died, 82 people were injured and 11,700 head of livestock were killed. Also, 218 family houses, 1,066 communication facilities, 750 fences and 26.3 million hectares of pasture and forest were burned (Goldammer, 2009). The total costs of property losses amounted to MNT 820.2 million. Ecological and economical damage were estimated at MNT 1,850.5 million (December 1999 value: ca. \$US 1.8 million).

Due to the extremely high number of fire occurrences and their extent, the period of 1996-2000 ranked highest in all fire parameters. As for the area affected by fires starting from 1980, some 25% of the country’s forest resources or 2.4 million hectares of land were destroyed and the damage amounted to MNT 32.6 billion in 1996.

3.4 Burned biomass calculation

Mongolia is a highland country located deep within the interior of Eurasia and has a marked continental climate with poor soil fertility, scanty surface water resources and harsh natural conditions.

Grassland comprises over 80% of its territory. It is assumed that most of today's steppe vegetation is on formerly forested sites that were degraded by fires. Wildfires constitute a major factor determining the spatial and temporal dynamics of forest ecosystems.

The burned biomass of each burned pasture type was extracted through a GIS integrated analysis of a pasture biomass map and a burnt area map.

According to results presented in the Global Fire Emission Database (GFED website) from 1997 to 2009, fire emission values of carbon, carbon dioxide and methane for all of Mongolia are seen to be fairly close to the average for Central Asian countries and constitute less than 10% of total emissions, except in 1997 (Fig. 7). These data were obtained from ORNL DAAC using the

citation of Randerson *et al.* (2010). The GFED model developers have issued a notification requiring these values to be used carefully so in this paper we have only included a statistical comparison and correlation of these components with burned biomass during this period.

The above air pollutants were well correlated with burned biomass calculated using remote sensing and GIS techniques, and Fig. 8 shows a positive correlation between CO₂ and burned biomass.

4. Conclusions

Our research showed that real time MODIS data is more accurate in fire-scar mapping than NOAA NDVI. This was proven by the overall accuracies obtained when the two sensors were used in the mapping of fire scars.

The fire statistics were analyzed for five-year periods, and due to an extremely high number of fire occurrences and extent of burning, the period of 1996-2000 ranked highest in all fire parameters (number of fires, burned area, damage, etc.).

Table 2 Burned biomass estimation.

Year	Total burned area, hectares (ha)	Total burned biomass, tons	Burned biomass per ha, tons/ha
1996	11,146,582.84	91,900,499.49	8.24
1997	12,840,587.58	106,228,449.24	8.27
1998	3,750,466.88	32,018,024.26	8.54
1999	3,199,709.26	24,857,472.19	7.77
2000	7,847,866.65	72,197,949.68	9.20
2001	855,241.39	9,112,004.08	10.65
2002	603,218.23	3,486,229.58	5.78
2003	3,083,190.77	27,910,489.36	9.05
2004	922,214.32	7,830,604.48	8.49
2005	725,093.30	6,756,216.46	9.32
2006	1,752,419.42	16,330,429.18	9.32
2007	3,026,175.43	24,742,481.26	8.18
2008	1,560,526.49	12,532,639.53	8.03
2009	1,004,219.31	5,475,135.04	5.45
2010	1,005,322.70	9,189,426.40	9.14

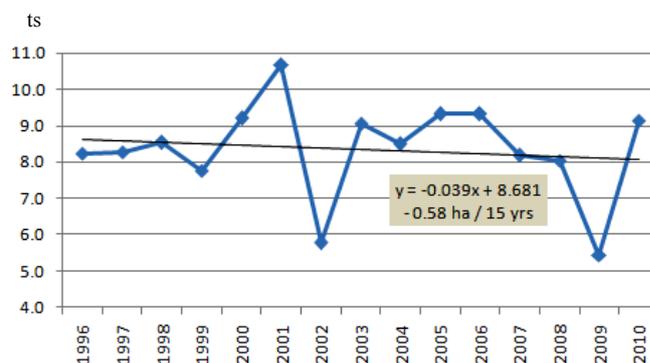


Fig. 6 Burned biomass per hectare area.

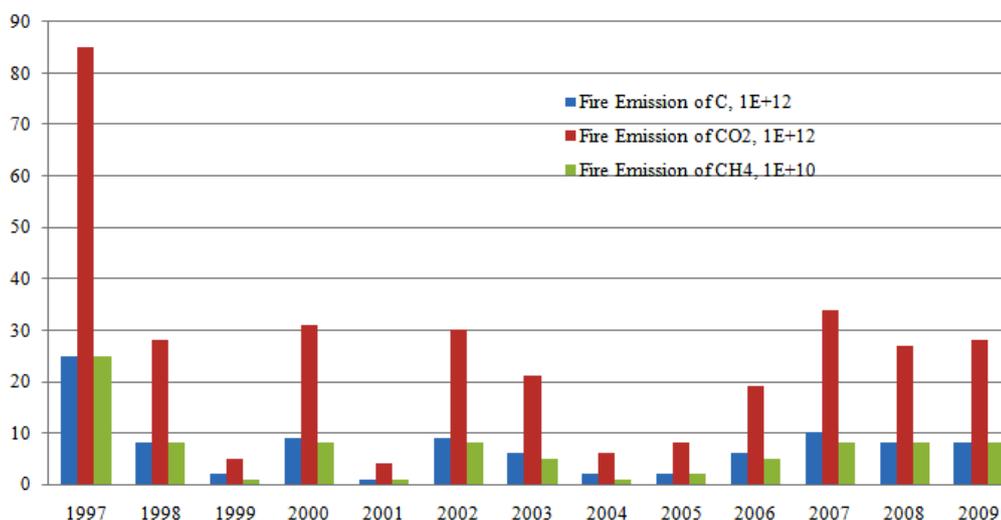


Fig. 7 Fire emissions of C, CO₂ and CH₄ over Mongolia. (from Global Fire Emission Data base)

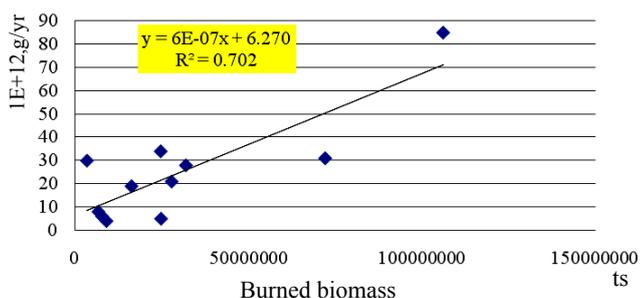


Fig. 8 Correlation between fire emission component CO₂ and burned biomass.

The burned biomass calculation was done first for pasture land. However, forest fires accounted for 22% of the total fires, and are therefore further needed to be considered in burned forest biomass estimation.

Results posted in the Global Fire Emission Database were used for Mongolia, considering only carbon, carbon dioxide and methane in order to compare these emissions values with burned biomass, and these three types of pollutants were found to be well correlated with burned biomass. Future studies should continue by examining this kind of correlation with other gases.

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Website:

<http://www.falw.vu/~gwerf/GFED/GFED3/tables/countries/>

Global Fire Emission Database:

Information and Computer Center, <http://www.icc.mm/>



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