FOREST FIRE MAPPING IN MONGOLIA – THE USE OF MODIS ACTIVE FIRE PRODUCTS FOR STRATEGIC FIRE MANAGEMENT

Daniel Wyss, Martin Fimiarz, University of Applied Sciences Berlin (TFH)

Contact: Wyss@tfh-berlin.de

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ABSTRACT:
Forest fires are one of the main causes for the drastic degradation of forest resources during the past 15 years in Mongolia. The transition to market economy has resulted in many socio-economic dislocations causing an increase of household poverty, vulnerability and pressure on the natural resources. Since the beginning of the 90's the duration, frequency and intensity of forest fires has grown significantly. 90% of the forest fires are man made and are linked to new livelihood strategies for income generation such as illegal deforestation and the intensive utilization of Non Timber Products (NTP). Currently Mongolia has approx. 12.9 Mio. ha of closed forests. In the years 1990 to 1999 Forest fires have occurred over an area of 7.3 Mio. ha (56%). The highest ever recorded forest fires were 2.3 Mio. ha in 1996 and 2.6 Mio. ha in 1997. Effective fire control and prevention is difficult due to missing communication facilities, qualified manpower, appropriate technology and the inaccessibility of many areas. This paper discusses the potential of satellite imagery to support strategic fire management based on the temporal and spatial distribution of active forest fires for the years 2000 to 2005 in the northern Aimags: *Selenge*, *Töv* and *Hentiy* using MODIS (*Moderate Imaging Spectroradiometer*) global daily active fire products with a spatial resolution of 1 km^2. The results will be compared with NOAA-AVHRR data which the National Remote Sensing Centre of Mongolia has been receiving since 1987. High-resolution LANDSAT ETM+ data as well as ASTER imagery have been used to validate the results and to quantify the extent of forest degradation using multitemporal analysis methods.

1. FOREST FIRES IN MONGOLIA – NATURAL AND ANTHROPOGENIC CAUSES

Every landscape has a specific fire regime and the methods of adaptation by vegetation types are divers. In the Taiga- und Sub-taiga forests, fire is a natural ecological factor which, in conjunction with climatic and edaphic factors, influences species composition and spatial distribution of forest ecosystems. (GOLDAMMER, 2002, MÜHLENBERG et al. 2003). The main natural cause for forest fires in the Taiga ecosystems is lightning during the summer months. (CHULUUNBAATAR, 1998). Aggressive fire prevention methods in these ecosystems can cause an ecological unbalance not only influencing species composition but also causing an increase of pest damage and higher levels of fire susceptibility. Besides forest fires which are characterized by two distinct fire seasons (spring and autumn), the main causes for forest degradation are illegal deforestation, insect disease, open mining and overgrazing. Since the transition to market economy beginning of the 1990's the duration, frequency and intensity of forest fires has grown significantly. 90% of the forest fires are man made and are linked to new livelihood strategies for income generation such as illegal deforestation and the intensive and unsustainable utilization of Non Timber Products (NTP) such as the collection of deer antlers, pine nuts, herbs and berries in the spring and autumn months. The main causes for forest fires are uncontrolled camp fires, smoking, bullets (hunting activities) and sparks from tractor exhausts. Fire hazards are additionally triggered by climatic droughts as experienced in 1996 and 1997 as well as in the year 2002. The seasonal outbreak of fires is linked to the socioeconomic activities resulting in a main fire season during the months March to June (80% of forest fires) and a smaller fire season during the autumn months of September to October with 5 to 8% of forest fires (*GOLDAMMER*, 2002).

Fires have been monitored in Mongolia using NOAA-AVHRR data since 1987 at the ICC (National Remote Sensing Centre) in Ulaanbaatar. The mapping of forest fires shows a continuous increase since 1990 resulting in extreme fire hazards in the years 1996 (10.7 Mio. ha) and 1997 (12.4 Mio. ha). In the years 1990 to 1999 a total 47 Mio. ha of burnt area was recorded of which 7,3 Mio. ha were forest fires (15% of total forest area). In addition to the described socioeconomic activities these extreme fires certainly also have been triggered by airborne fire suppression activities of the Aerial Patrol Service (APS) during socialist times resulting in an accumulation of highly flammable fuels. The effective management of forest fires and ecologically based fire prevention methods as well as the establishment of an early warning system in Mongolia is very limited due to the lack of decentralized communication facilities, education, fire fighting equipment and the accessibility to remote areas as the current state of infrastructure is inadequate. These factors show the importance of satellite-based fire detection to visualize spatial patterns of fire occurrence as a basis for the implementation of ecological sustainable fire prevention methods as well as for accurate mapping of burnt areas to quantify the actual loss of forest resources.

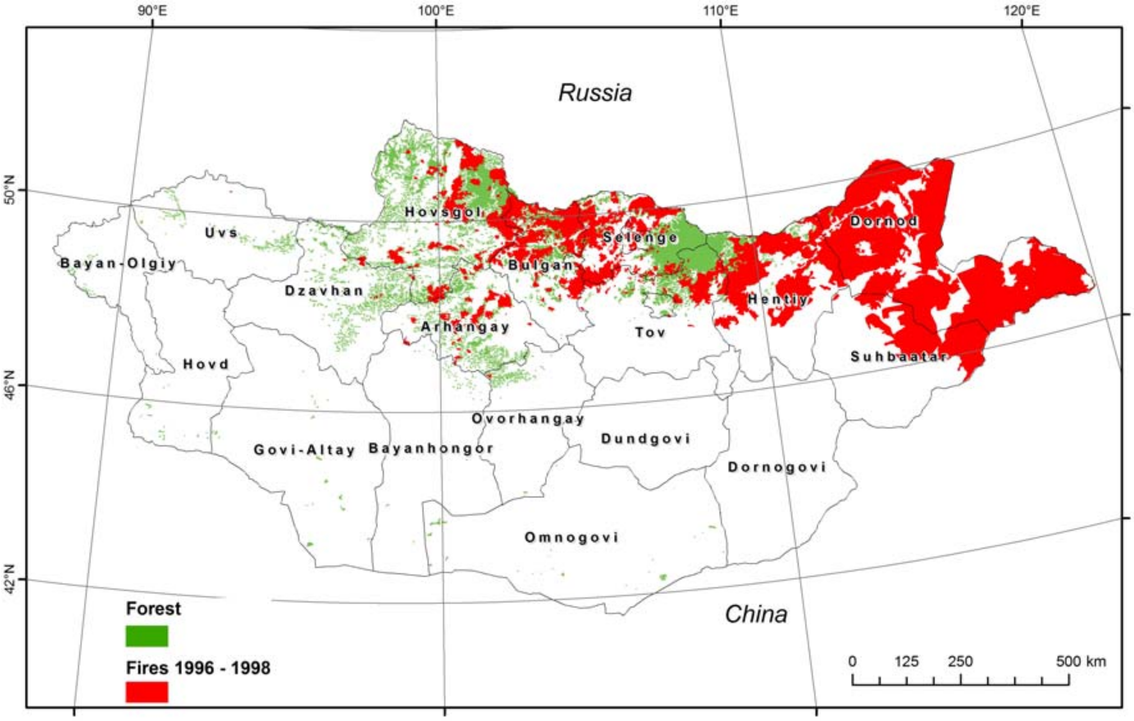

Figure 1: Distribution of Forest and steppe fires in the years 1996 to 1998
Source: ICC, Ulaanbaatar

2. SATELLITE BASED MAPPING OF ACTIVE FIRES USING MODIS DATA

The first satellite sensor which has specifically been developed to assess fires is MODIS (*Moderate Resolution Imaging Spectroradiometer*) onboard the TERRA-EOS Satellite (NASA) which was launched in the year 1999 (KAUFMANN et al 1998). Advantages of MODIS are the free availability, the high temporal resolution (1 – 2 days), the large coverage (swath of 2330 km) which enables environmental analysis on a supraregional level and the number of spectral bands (total of 36 bands covering VNIR, MIR and TIR). These aspects compensate for the low spatial resolution of 1 km^2. In addition, a large variety of derived products such as Active Fires (1 km resolution), NDVI and LST (Land Surface Temperature) with a resolution of 250 – 500 m or Land Cover products with a resolution of 1 km are freely available. For an effective fire management a higher temporal resolution than 1 day is necessary. For this reason the MODIS team initialized a MODIS "*Rapid Response System*" in the year 2001 providing information on active fires in "*Real Near Time*" (interval of 2 – 4 hours after image recording, JUSTICE et al. 2002). These Products are available in the WWW for selected areas. Another alternative to interactively access fire information is the use of the „*Web Fire Mapper*" *(http://maps.geog.umd.edu/*) which has been developed by the University of Maryland (USA).

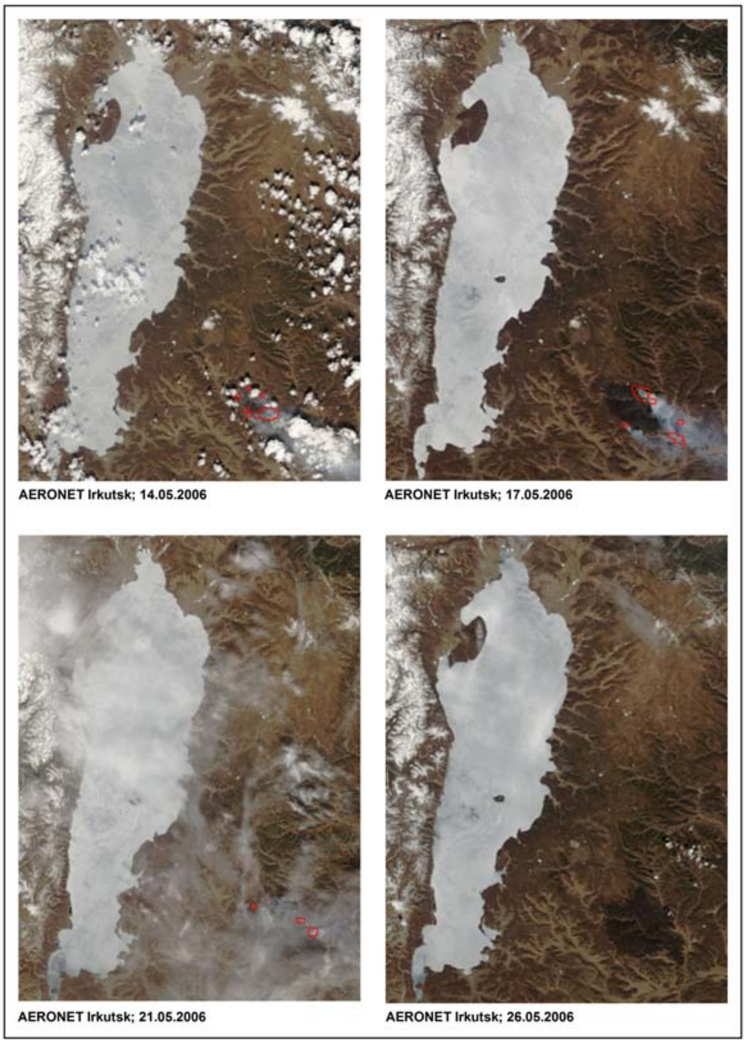

Figure 2: MODIS Rapid Response System: Visualization of active fires southeast of the lake *Hovsgol-Nuur*, *Hovsgol* Aimag, Mongolia (14.05.2006 to 26.05.2006).
Source: *http://rapidfire.sci.gfc.nasa.gov/subsets/AERONET_Irkutsk*

In the following study MODIS active fire products have been used to monitor the temporal and spatial characteristics of forest and steppe fire within the buffer zone of the *Khan Khentii* special protected area (KKSPA) in Mongolia, covering the northern Aimags, *Töv*, *Selenge* and *Hentiy*. For this purpose, free available MODIS active fire products which are accessible over the DAAC (*Distributed Active Archive Center*) of the NASA in a hierarchical Data format (HDF-EOS) have been processed for the years 2000 up to 2005 with the aim to access quantitative and qualitative information on fire occurrence. The high temporal resolution of the fire products (daily or as an 8-day composite) were used to generate fire statistics on an annual basis.

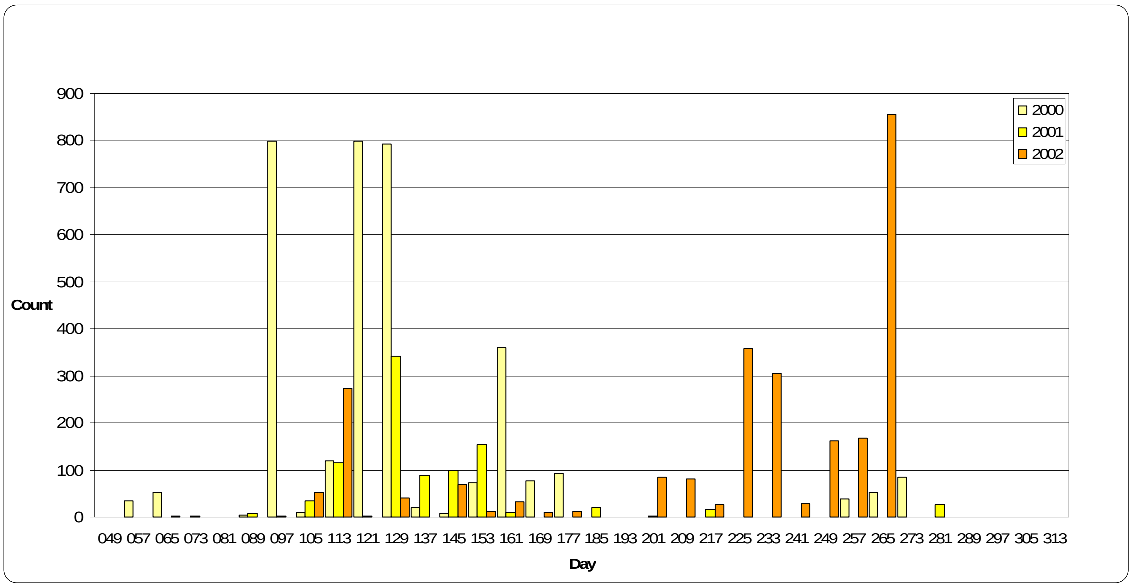

Figure 3: Temporal distribution of forest and steppe fires fort the years 2000 to 2003

The statistics in *Figure 3* show a significant main fire period starting in March (day 089) which declines in the summer months due to more intensive rainfall and a second fire season in autumn starting end of August and lasting until the middle of October (day 181). The spatial distribution of the active fires can be seen in *figure 4*. The highest fire activity was recorded in the years 2000 and 2002 with a total of 2979 pixel in 2000 and 2353 pixel in 2002. This accounts for approx. 200,000 ha burnt area in both years. The years 2001, 2003, 2004 and 2005 show a decrease of fire activity with a mean burnt area of approx. 70,000 ha

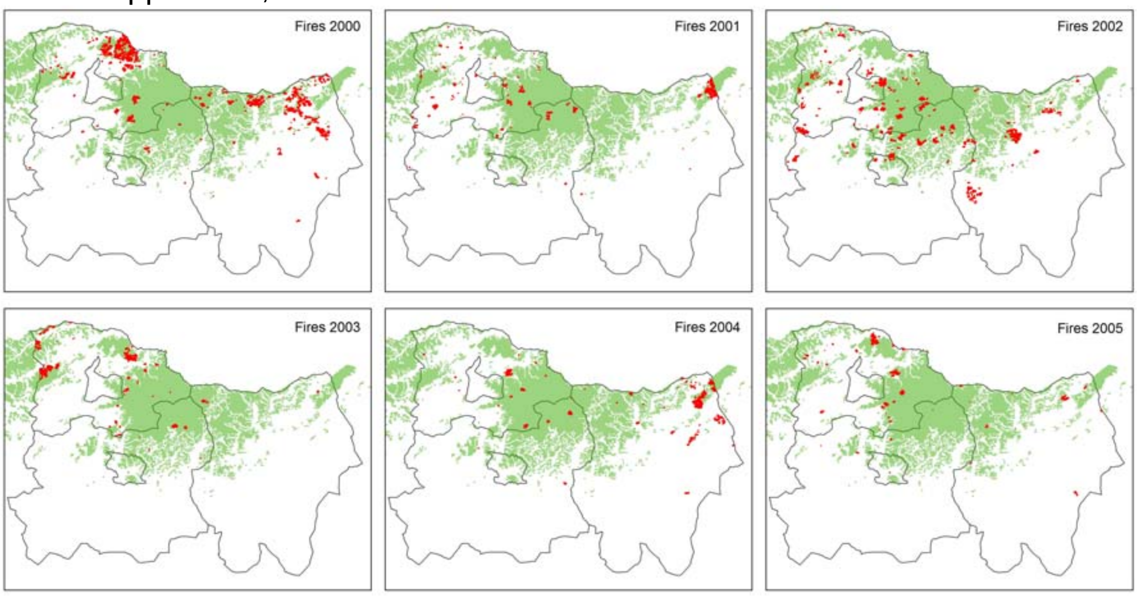

Figure 4: Spatial distribution of forest and steppe fires in the central aimags: *Töv*, *Selenge* and *Hentiy* for the year's 2000 to 2005.

The spatial overlay of all fire occurrences shows a distinct concentration of fire activity within areas of main socioeconomic activity, especially along the main development axis in proximity to the transmongolian railway, starting in Ulaanbaatar and continuing North in direction of the main town *Darchan* up to the Russian border towards *Suk-*

hbaatar (main town of *Selenge* Aimag). A second concentration of fires can be seen in the northwest of the *Hentiy* aimag as a result of higher continental climate with less annual rainfall in comparison to the eastern areas. In total 780.000 ha of Forest and steppe fires were recorded, of which 50% account for forest fires when overlaying the result with MODIS land cover products of the year 2003.

3. MAPPING OF FIRE SCARS AND COMPARISON WITH NOAA-AVHRR DATA

The validation of the MODIS active fire product was carried out on the base of high resolution LANDSAT 7 ETM+ imagery with a resolution of 30 m (MS) and 15 m (PAN) which are freely available up to the year 2003 using the GLC*F (Global Land Cover Facility*) website of the University of Maryland (USA). The visual interpretation of fire scars was performed using the band combination 5, 4, 3 (RGB) which showed the highest information in respect to burnt areas. The *figure 5* shows an example taken from a LANDSAT ETM+ image from June 2000 overlaid with MODIS fire pixels. Despite the low accuracy of 1 km (MODIS) the relative geometric accuracy of the active fire pixels is high. The high temporal resolution of the MODIS active fire products also allows the visualization of fire spread over time. The detailed mapping of affected areas needs to be performed on the base of high resolution imagery. Due to current technical problems of the LANDSAT series, alternative Imagery such as ASTER of SPOT can be used for visual or digital classification of burnt areas.

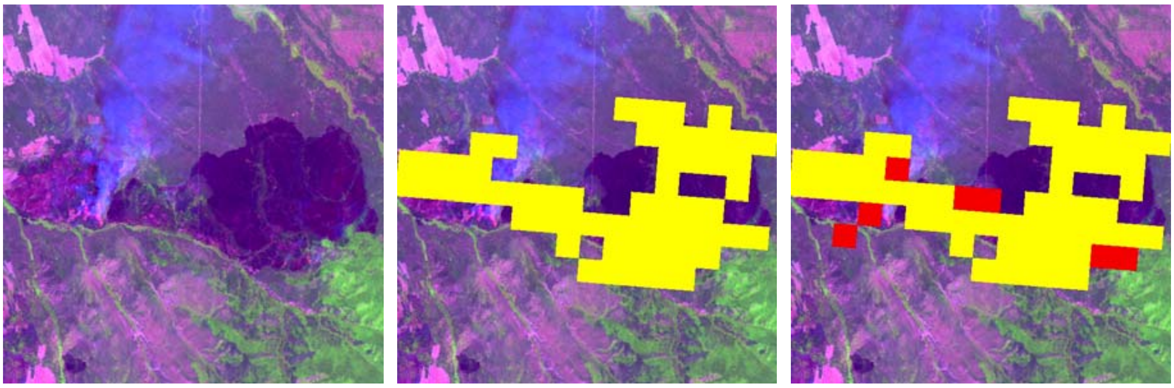

Figure 5: Steppe fire in Russia near the Mongolian border. MODIS active fire products from the 18th of June 2000 (yellow) and 26th of June 2000 (red) in comparison to a LANDSAT ETM+ image (acquisition date: 26th of June 2000).

The comparison between MODIS active fire products and the classification of the ICC NOAA-AVHRR data for the years 2000 to 2005 show significant differences. In the 5-year period 620,000 ha of forest fires were interpreted on the base of AVHRR data, nearly twice the amount of recorded forest fires using MODIS. The AVHRR-interpretations show similar spatial patterns but seem largely over interpreted. According to STOCKS et al (2001) the MODIS sensor shows considerable advantages in detecting smaller and more detailed fires. The results of NOAA and MODIS (years 2000 to 2002) were compared using a LANDSAT ETM+ image of September 2002 (*see figure 6*). The overlay of visually interpreted fire scars with detected MODIS fires showed a high level of correspondence (match of 70%) in comparison to AVHRR fire data with a correspondence less than 20%. This example shows the excellent suitability of MODIS active fire products to quantify the actual loss of forest resources.
The exact quantification of burnt areas can best be achieved using methods of multitemporal image analysis which has been performed within selected areas of the KKSPA buffer zone using additional LANDSAT TM data of 1989. The combination of

digital classification results with freely available SRTM data (*Shuttle Radar Topography Mission*) enables a modeling of fire risk and fire propagation using derived topographic parameters such as slope, elevation and aspect. Examples will be shown during the presentation at the ACRS (2006).

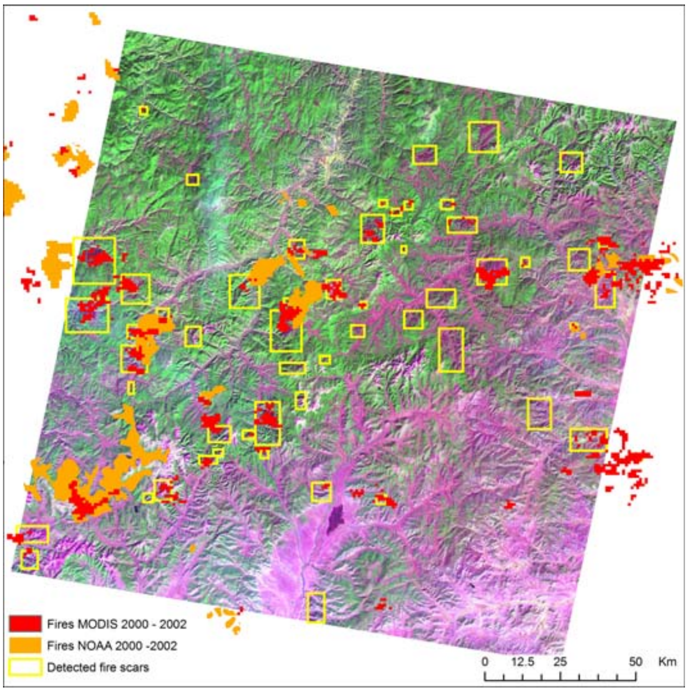

Figure 6: Interpreted fire scars (yellow boxes) in comparison to detected NOAA-AVHRR and MODIS active fire data on the base of a LANDSAT ETM+ image from September 2002 displayed in the band combination 5, 4, 3 (RGB)

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