# THE IMPACT OF FOREST FIRE ON FOREST COVER TYPES

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**Abstract:**

The objective of this study was the impact of forest fire on forest cover types. This study has identified non-forest and forest area which has 4 forest class were included with evergreen, coniferous, deciduous, mixed forest, it has been used from Landsat-5 Thematic Mapper (TM) data. Several classification approaches have been used for classification of satellite imagery. Addition to current classification has developments in segmentation and object-oriented techniques offer the suitable analysis to classify satellite data. In the object-oriented approach, images were segmented to homogenous area as forest types by suitable parameters in some level. The accuracy analysis revealed that overall accuracy showed a good accuracy of determination (86.3 percent in 2000 and 93.7 percent in 2011) with regard to identify of the forest cover and type. Furthermore, these result suggest that the Landsat TM imagery can reliable detect the forest type based upon the segmentation and object-oriented techniques.

**Keywords:** Landsat, Forest cover, fire, classification

**Introduction**

Mongolia is situated in Central Asia bordered on the north with Russian Siberia, the east and south by the Chinese territory of Inner Mongolia and to the west by the Chinese province of Xianjing. With a land area of 1.565 million km2, Mongolia is about six times the size of Great Britain, or about the same size as the US State of Alaska. (World Bank, 2004). The forest of Mongolia is growing terrestrial dry and harsh climate, therefore forest capacity, natural growth, and resilience are absolutely low, and very easily lost ecological balance, because of natural and human impacts, including dryness, fire, pesticide and disease (Ch.Dorjsuren, 2007). According to the National Statistic Office, NSO (NSOSTAT data 2000), the boreal forest and steppe forest zones contain a coniferous component composed of Siberian larch (Larix siberica), Scotch pine (Pinus sylvestris) and Siberian pine or cedar (Pinus siberica), and a smaller broad-leafed component composed primarily of birch (Betula platyphylla), aspen (Populus ttermula) and poplar (Populus diversifolia). Over 90% of northern forests are encompassed within seven provinces: Khuvsgul (29%), Selenge (16%), Bulgan (14%), Kentii (11%), Tuv (10%), Arkhangai (8.5%) and Zavkhan (5%).
Mongolia has a typical continental climate, with hot summers (temperature up to 410C) and cold winters (temperatures to -530C). Rainfall is relatively low, varying from 50 mm in the southern desert region, to 450 mm in mountain areas, with 80% ~ 96% falling in the warm period from May to September (Erdenetuya, 2012). According to scholarly surveys, about 56 per cent 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 territories covered with forests are in a zone assessed as of highest fire risk (Erdenetuya, 2012).
Wildfires constitute a major that determine spatial and temporal dynamics of forest ecosystems (Goldammer, 1999). In Mongolia, fire is a major factor which determines spatial temporal dynamics of forest ecosystems (Chuluunbaatar, 1998).
In recent years, increasing negative effects on natural forest ecosystems especially due to forest fires, spread of forest pests and diseases and various other reasons including human influences, have been recognized. At the same time, the amount of wood available to meet demands by households and industry are increasing. The government has recognized that wood imports are necessary to meet supply shortfalls and to discourage illegal logging. Hence customs duties on some types of wood and timber imports have been removed.
The country's forest resource is not very rich in extent or quality, covering an area of 17.5 million ha on the southernmost fringe of the Great Siberian forest and

some mountain ranges western and north-western part of Mongolia territory. (J.Tsogtbaatar, 2004).

Although in the Law on Forests is required to implement detailed research again on the forest database which changes periodically every 10 years, we cannot monitor the forest areas' changes depending on current forest research equipment and technology, funds and capacity. For the Mongolian forest inventory a use of old aerial photography from 1970s to 1980s data and a visual estimation in the field work are necessary.

The forest area has decreased by 1.2 million ha during the last 30 years from 1974 to 2006, but environmental and human impacts such as, burnt forests, logging, open forests are as increased by 3.2 million ha during the period (MNE, 2006). According to FAO statistics, present forest resources of the country indicate that Mongolia has a small amount of forest resources which have been decreased by human impacts, fires, insects and illegal logging. (MNE, 2001). Moreover, it was noted that the occurrence of wildfire and distribution of forest pests were increased which statistic from 2010-2013 mention report of the nature and environmental of Mongolia (S.Bayarkhuu., 2014). The forest functions map and forest management plan. According to (B.Ochirsukh et al., 2011), geospatial technology approaches and data are mapped the forest functions using GIS Therefore, we need to establish and expand a harmonized approach with application of geo-informatics for determination of forest resources in order to use for its management at decision making/planning and management level. However, the use of high-resolution data has a limit in the process of pixel orientated classification mainly adopted to medium spatial resolution image according to (Blaschke and Strobl, 2002; Hofmann, 2001; Limp, 2002; De Jong et al., 2000). Also, it was noted that new image classification approach, the method of object-oriented classification which thought as important the spatial-relations of the pixels which compose an image attracts attention. Since it has the classificatory function which gave the hierarchical structure that image analysis software, eCognition (Definiens Imaging, Germany) which has adopted this classification method in this object-oriented classified a forest and the classified object into a coniferous forest and a broadleaved forest further after classifying into a forest and non-forest first, it can be identify that it is suitable for the detailed classification of a forest area (Ursula et al., 2004). Also we needed to identify immediate forest change detection. For this purpose, high spatial resolution satellite data is necessary and it would be used for forest inventory, for forest mapping and forest change detection. Forest cover types, disturbance regime maps and forest change detection maps will be developed in order to inform government agencies on the current status of forest resources. Current image is very important for mapping and change detection analyze.

**Objectives**

The objective of this study aimed to determine the fire impacts on forest types and forest cover changes using Landsat satellite data. To implement this objective, we focus on following goals,

- To evaluate forest cover change from different temporal scales,
- To determine how the forest fire influences the forest cover types and their changes.

**Study area**

The Eruu soum is situated in Selenge province of north part of Mongolia, approximately 360 km from capital of Ulaanbaatar. The study area is located within the sub-tundra and forest steppe zone (N 49$^0$00'-50$^0$00', E 106$^0$00'-108$^0$00'), which occupies approximately 8394.2 km$^2$, which forest area has covered about 96.1% of the land (Figure 1). The main forest types in the rea is dominated by birch, aspen, cedar, fir, larch and pine. The average altitude is 1400 meters above sea level.

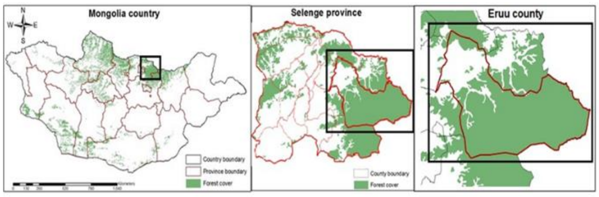


Figure 1. Study area location

The mean annual temperature of about 7.0$^0$C while the mean monthly temperature ranges from -22$^0$C to 19$^0$C. A maximum temperature of 36.4$^0$C is recorded in June, and minimum temperature of -40.1$^0$C is recorded in January. Annual amount of precipitation is 276 mm and most of it falls between May and September. (Azzaya, D., Munkhzul, D., 2007).

**Data and dataset**

In order to investigate the Landsat-5 Thematic Mapper (TM) and Landsat-7 Enhanced Thematic Mapper Plus (ETM+) images were acquired in the early 2000s and 2011 were used (14 April 2000, 13 September 2000 and 20 September 2011) for path 131-row 25-26, respectively. In order to reduce scene to scene variation related to sun angle, differences in atmospheric condition. In addition, cloud cover is minimal in all images. Digital number values were converted to radiance, and ground-leaving reflectance were created from radiance using the 6S algorithm (Vermote et al. 1997). Also we were collected thematic maps and ancillary datasets (Table1.)

Table 1. Used data and software

| Satellite | Sensor | Date acquired | Spatial resolution (m) |
|---|---|---|---|
| Landsat | ETM+ | 14 April 2000 | 30 |
| Landsat | ETM+ | 13 September 2000 | 30 |
| Landsat | TM | 20 September 2011 | 30 |
| **Thematic data** | | | |
| Topographic maps | | | |
| Forest inventory map | 2009 | | |
| **Ancillary data** | | | |
| Forest fire information by MODIS 2000 – 2011 (burnt area) | | | |
| Forest statistic data | 2007 | | |

A combination of image processing software: ArcMap, ERDAS Imagine, ENVI and Definiens developer software were used throughout the all process.

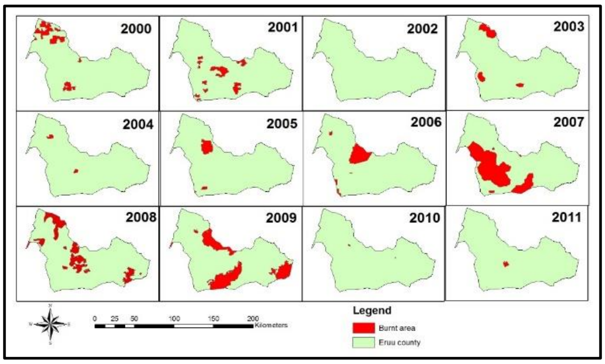


Figure 2. Burnt area map from MODIS image of study area (2000 to 2011)

We have been used burnt area distribution image by MODIS and square in each year from 2000 to 2011 for data analysis in this study (Figure 2). According to the fire statistics of 2000-2011, biggest fires of 1065-1972 $km^2$ area is occurred in Eruu soum. For example, during 2007-2009 that period has high frequently in region of study area (Figure 3).

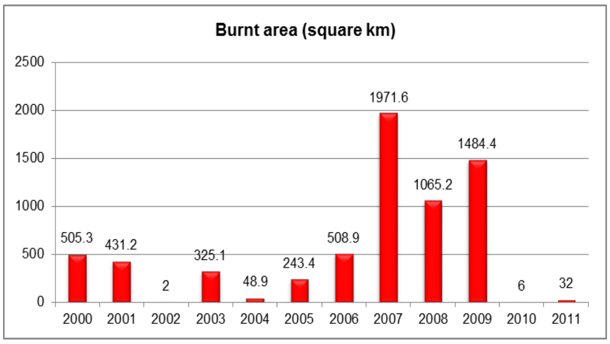


Figure 3. The change of burnt area from 2000 to 2011 in study area

**Methodology**

We used Definiens Developer software (formerly eCognition) to segment and later classify image objects. Object-oriented method In general, the object-oriented approach and the image analysis process can be divided into the two principal workflow steps, segmentation and classification.

*Object-oriented techniques:* The meaningful primitive objects, which obtained by segmentation, can be classified through two methods: Sample-based classification by nearest neighbor classifier and rule-based classification by membership function technique. The experiences were showed that when several different feature order objects into classes, the nearest neighbor method should be used and when only few discrete features can separate classes from each other, use of membership function is optimal choice.

The nearest neighbor classifier, as a supervised classification method needs training area in multidimensional feature space. It would be useful when user has no knowledge to describe feature spaces. In the nearest neighbor method or the sample-based method, the primitive objects are classified through similarity to training units or segments for each class. The rest of objects in the image are belonged to their nearest sample in each class. It usually uses spectral attributes; the objects will have extra information such as shape, texture, context attributes and topological relations between neighborhoods and other objects. This information can be used for extraction of each class in classification (Shataee et al., 2004).

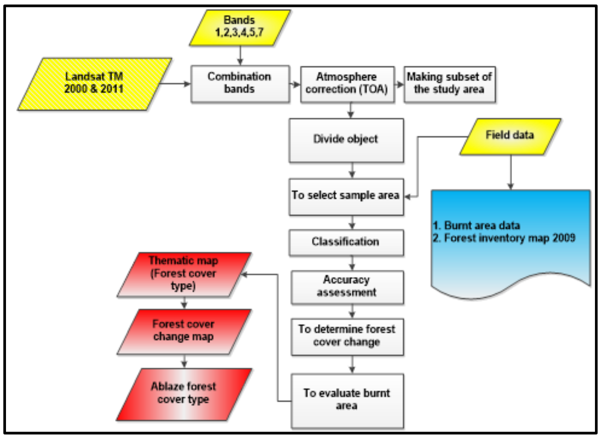


Figure 4. Methodology scheme

**Results and discussion**

Figure 6 shows the classified satellite images in 2000 and 2011. These images identified about 14 cover classes with a description of 9 vegetation cover including 8 forest cover types using 30 m spatial resolution Landsat TM data (Figure 6). Particularly, in 8 forest cover types included cedar, pine, larch, birch, shrub and three types of mixed forest.

Central and south area of Eruu soum was affected by fires in 2007-2008 and this burnt area was clearly

detected by satellite image in 2011 (Figure 6). Vegetation cover type in this burn area was replaced with grass land and barren land in 2011.
The forest cover area has decreased by 5.03% and non-forested area has increased by 11.9% in 2011 compared to 2000. According to our study results, larch was extremely decreased by 50.4% due to forest fires in Eruu soum area. However, readers can pay attention on an accuracy of our used methodology that is approximately 80%. Increases in cedar by 22.4% may relate with classification methodology because cedar can be mixed with other class type.
In general, pine is dominant in birch and pine mixed forest, larch is dominant in birch and larch mixed forest. After the burning pine and larch, they can be replaced by birch in naturally and rapidly. In addition, occurrence of forest fires depends on forest types, precipitation distribution and availability of fire sources. (Goldammer., 2007). Figure 5 and 6 show forest cover type changes replaced by other forest cover types after burning. Forest area in central and east parts of Eruu soum in 2000 was changed to grassland and birch area in 2011 due to forest fires (Figure 5 and 6).

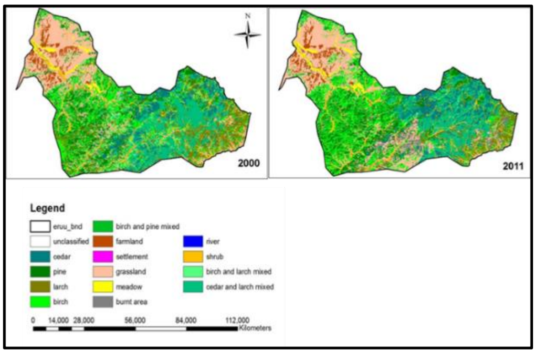

Figure 5. Classified maps in 2000 and 2011

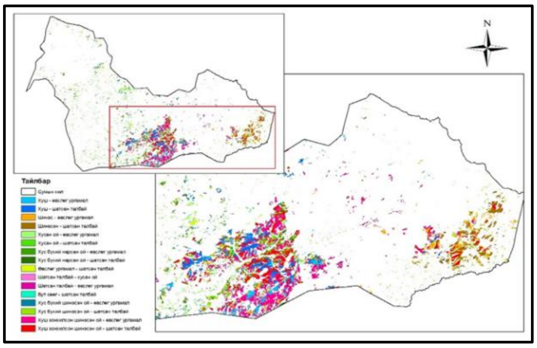

Figure 6. Change detection map of burnt forest areas compared in 2000 and 2011

About 17211-hectare area covered by birch and 16128-hectare cedar and larch mixed area were replaced by grassland area (Figure 7). Totally 25239 ha of forests were changed to burnt area and 52603 ha forests were changed to grassland (Figure 7).

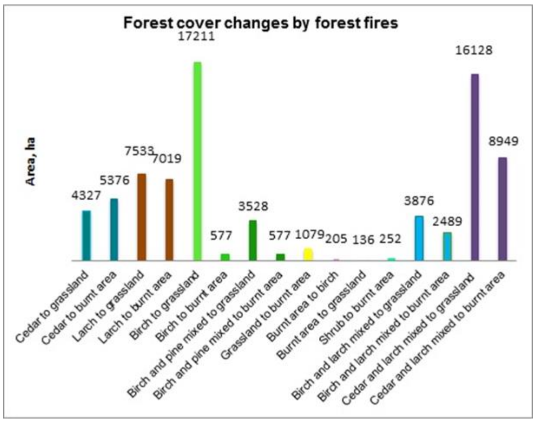

Figure 8. Forest cover changes by forest fires detected in 2000 and 2011

**Accuracy assessment**

Accuracy assessment is very important for verification of classification results. In mathematics, the computation of probable error of classification is very complicated. But in practice, we often assess the classification accuracy by means of examining samples and computing the error matrix from the statistical comparison between each interpretation and the ground data. In order to evaluate the usefulness of geographic data for forest cover type classification, we also used object-oriented classification method of Landsat imageries.
The result of the object-oriented classification of the Landsat images were compared using a forest inventory map of 2009, Google Earth map, winter time images, digital elevation model (DEM) and burnt areas statistic data that has already been prepared in another project.
The overall accuracy of forest cover type map was 86.3 % in 2000 and 83.7 % in 2011.

**Conclusions**

In this study, Landsat TM data from 2 different time period for forest cover types classification are used and the study area covers 7 forests types.
The results of accuracy assessment showed that the object-oriented techniques could classify forest types better than the pixel based classification method. In the results of the object-oriented classification, those are assumed as a homogenous area and an object.
The overall accuracy of the forest type maps was 86.3% for 2000 and 83.7% for 2011.
According to the fire statistics of 2000-2011, biggest fires of 1065-1972 sq.km areas occurred over Eruu soum during 2007-2009. The study area is high-risky region to forest fires.
The fire impact assessment results showed that 25239 ha of forests were changed to burnt area and 52603 ha forests were changed to grassland.

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