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DETECTING BURNT FOREST DAMAGE USING DIGITAL SPOT IMAGERY[1]

Deteksi Kerusakan Hutan Terbakar Menggunakan Citra SPOT Dijital

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ABSTRAK

Mendeteksi kerusakan hutan melalui metode inventarisasi terestris dan/atau potret udara membutuhkan biaya yang mahal dan memakan waktu, khususnya untuk luasan yang besar. Dalam paper ini, penulis menguraikan kegunaan dari citra SPOT dijital untuk mendeteksi kondisi hutan paska kebakaran. Evaluasi dilakukan terhadap empat kelas kerusakan hutan yang terbakar.

Studi ini memperlihatkan bahwa citra SPOT multispektral dapat digunakan untuk mengklasifikasi hutan terbakar menjadi kelas dengan tingkat kerusakan ringan, sedang, berat dan sangat berat. Analisis spasial yang juga dilakukan dalam studi ini memperlihatkan bahwa sebagian besar areal studi termasuk kategori kebakaran berat dan sangat berat. Meskipun hutan-hutan bekas tebangan baru cenderung mengalami intensitas kerusakan yang tinggi, kebakaran yang terjadi tahun 1998 tidak hanya membakar hutan bekas tebangan baru tetapi juga hutan bekas tebangan tua dan hutan primer.

INTRODUCTION

At present, most of forest management practices need timely and good quality of data/information for forestry applications. For forest fire management, it has been proven that satellite remote sensing offers very valuable information at various aspects of fire management problems, either at pre-fire planning, during fires or at the post fire, such as detection, suppression and mapping of burnt area. After fires, remote sensing system may provide information on forest damage quickly with high accuracy. After 1998 fires in East Kalimantan, only few organizations/companies that used digital satellite imagery to evaluate post-fire condition. Many of them used conventional ground survey to estimate the extent and stand condition which are usually time consuming and costly.

Availability of data in digital format coupled with better quality of computer technology, facilitate to map forest or land cover with per-pixel classification techniques

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because land/forest cover is directly related to pixel values on image. From previous experiences, it has also been proven that fine resolution of satellite data such as TM, SPOT and MESSR are useful for forest management. In this study, the author emphasized on the use of digital SPOT imagery for assessing post-fire vegetation condition.

At the present time, of several available satellite imageries, SPOT imagery offer several advantages over traditional photogrammetric. One SPOT scene covers approximately 360.000 ha, equivalent to almost hundreds of medium-scale aerial photos. The SPOT data are now available world wide on a constant cycle basis that may useful for forest monitoring. The availability of the data in digital formal also enable us to perform automated operations such as geometric correction, radiometric correction, edge/line detection, classification etc.

From February to April 1998, an extensive forest fires raged out of control through various parts of Southeast Asia including major part of East Kalimantan, Indonesia. During this period, the occurrence of fires was monitored using daily-acquired NOAA AVHRR and GMS imageries. Unfortunately, coarse spatial resolution of these two images makes them impossible to be used to detect the area of burnt forest. Finer spatial resolution of SPOT HRV data of only 20 m x 20 m, enable us to estimate post fire condition of burnt forest. In this study, SPOT data were used to zoom in the burnt area to accurately determine the nature of fires where possible.

The 1998 fires in East Kalimantan had caused serious impacts on forest and other vegetations as well as on socio-economic aspect of the community living surrounding the forest. The official estimate for the burned area in 1998 is about 507,239.5 ha causing financial losses amounting to Rp. 10.06 trillion. It was also reported that although in 1997 East Kalimantan Province was recognized as the most prepared in term of fire control, in early 1998, the fires had raged and intensified in March and April following a pattern similar to the 1982-1983 episode. It was reported that the 1998 fires were caused by large-scale land clearing. From 507,239.5 ha burnt, some of 315,132 ha (62.2%) were logging concessions. Only 1,857 ha of community agricultural lands and 10,758 ha of community plantation (estate crops) were burnt, while the rest were forested area.

In East Kalimantan, ITCI Ltd. concession area located in Southern part of East Kalimantan Province also suffered from fires. Within ITCI Ltd. concession area, the fire occurred from February to April destroying major part of the area. As we all may aware that fires remove vegetation cover, reduce ecosystem quality and species diversity as well as cause serious economic losses. Now, several logging companies face post-fire problems including implementation of rehabilitation techniques on burnt area, as well as techniques for salvage logging. Prior to develop rehabilitation and salvage logging plans, the evaluation of post-fire vegetation should be made. In order to provide timely and accurate information, the post-fire condition was evaluated using digital SPOT imagery.

The study was performed:

- to detect burnt forest damage quantitatively from digital SPOT HRV imagery;
- to evaluate whether the SPOT HRV could discriminate all damage classes;
- to evaluate the relationship between the age of logged over forest (annual cutting year) and the damage classes.

MATERIAL AND METHODS

Test Site and Supporting Data

The test site was ITCI Ltd. concession area, East Kalimantan, which is located between South-latitude 0°15’00” and 1°00’00”; and East-longitude 116°15’00” and 117°00’00”. Inside the test site, ground survey for data and information collection related to forest damage was conducted. All data and information obtained were then analyzed to support image processing, at the Laboratory of Forest Inventory, Faculty of Forestry, Bogor Agricultural University.

Two scenes of SPOT HRV (multispectral) imagery covering the major part of the study site were used. The scene centers are S000°30’12” and E116°42’25” (K302/J351); and S001°00’14” and 116°35’43” (K302/J502), acquired on June 5th 1998, approximately two months after fire.

Ground survey was performed two months after fire in order to achieve the study objective. To perform geometric correction and spatial analysis, the following maps were used as reference:

- topographic maps with scale of 1:50,000 and 1:100,000; and
- cutting year and forest potential maps of 1:100,000 scale

Software and Hardware

ER Mapper 5.5 image processing software was used to perform an image analysis of the SPOT data. The classified image was then overlaid with annual-cutting block map and spatially analyzed using GIS software ArcView Ver. 3.1 and ArcInfo, installed on PC IBM Compatible, and its essential accessories.

Methods

The procedure included the following steps:

- Geometric correction (Image-to-map rectification);
- Digitizing the annual cutting block boundary from the existing map and road from monitor screen;
- Establishment of forest damage categories;
- Assessment of accuracy;
- Image classification; and
- Spatial analysis.

Geometric Correction

Prior to performing other analysis, the images were accurately geo-corrected. Spatial interpolation using affine transformation equation, followed by intensity interpolation using nearest neighbour algorithm were conducted to get root mean square error (RMSE) less than 0.5. The first images (K302/J351) were rectified using 10 GCPs, which provided RMSE of 0.1 pixels, while the second images were geo-corrected using 13 GCPs with RMSE of 0.16 pixels. In order to perform image classification the two images were then mosaicked.

Establishment of Forest Damage Category and Land Cover Classes

The results of the study are expected to be used as reference in the implementation of rehabilitation techniques. The following four classes of forest damage classes performed by ITCI-Faculty of Forestry IPB (1998) were used:

- Unburnt tropical forest
  This class consisted of unburnt natural and logged-over tropical forests mostly located in the southern part of the study area. Mangrove forest, which dispersed in Balikpapan Bay are also included in this class. The predominant tree species are Shorea spp (meranti), Dipterocarpus spp (keruing) and Dryobalanops spp (kapur). On specific and limited site, Agathis borneensis was also occured.
- Unburnt plantation forest
  This class consisted of unburnt plantation forest (timber estate) within the ITCI Hutani Manunggal Ltd. (IHM) territory and rubber plantation of other estate crop companies including community agricultural lands, homogenously distributed in the area.
- Bare land
  This class is a land without vegetation or very sparse vegetation cover, includes roads; base camps, log yards, gravelpit, paved surface in Eastern part of ITCI Ltd. and other forms of bare lands.
- Slightly burnt forest
  This class is a forest area that has predominant healthy life-trees of more than 75%
- Moderately burnt forest
  This is a forest area, which has healthy life-trees ranging from 50% to 75%
- Severely burnt forest
  This is a forest area, which has healthy life-trees ranging from 25% to 50%
- Extremely burnt forest
  This is a forest area, which consisted of healthy life trees less than 25%.

The conditions of forest cover classes are shown in Figure 1.

During ground survey, tree conditions are grouped into (a) healthy life-tree (pohon sehat), (b) partially burnt life-tree (pohon merana), (c) marketable dead tree (pohon mati baik) and totally burnt tree (pohon mati hangus). The condition of each affected tree is shown in Figure 2.

(a) (b)

(c) (d)

Figure 1. Ground condition of several forest damage classes (The photos were taken on April 30, 1999 by author) (a) Unburnt tropical forest, (b) Slightly burnt tropical forest, (c) Moderately burnt tropical forest (upper-left part of the image), severely burnt tropical forest (upper-right part of the image). Unburnt tropical forest (lower part of the image), (d) Extremely burnt tropical forest

(e)

(f)

(g)

Figure 1. Continued (e) Burnt Land Clearing; (f) Burnt plantation forest (Acacia mangium) and (g) Unburnt plantation forest (middle part of the image)

(a) (b)

(c) (d)

Figure 2. Photos of tree condition (a) Healthy life tree; (b) Partially burnt life-tree; (c) Marketable dead-tree and (d) Totally burnt tree

To reduce misclassification during computer-assisted processing, the coverage of cloud and cloud shadow were separated as individual cover classes.

Digitizing the Annual Cutting Block

The polygon of logged over forest were digitized from the map of annual cutting block. To get more realistic information from the map, personal interview to the staff of Planning Division of ITCI Co. Ltd. pertaining the realization of logging activity was done.

While roads were digitized on monitor screen, by tracing a mouse cursor along the center of each road. The digitized pixels were then saved as a vector format (Arc/info format)

Image Analysis

In this study, a hybrid of supervised and unsupervised classification was applied. The unsupervised classification using isoclass algorithm was performed by generating a number of unlabelled classes. This is particularly useful to facilitate training area selection.

Based upon data and information available from maps coupled with ground truth data, a set of training areas representing each class performed above was then generated. The training areas were selected interactively by comparing ground truth data and their appearance on screen. To reduce error during placement of the training site, the ITCI Ltd. concession area boundaries map as well as road and river maps were overlaid. In general, the training area was plotted at the middle part of homogenous area.

To determine whether the SPOT data provide accurate classification, accuracy assessment and interclass separability analysis were conducted. The accuracy was estimated using overall and Kappa accuracy measures, while the separability analysis was evaluated using Transformed Divergence measure. The classified image was exported to ArcInfo format for spatial analysis using ArcView. In general, the flow of data analysis is depicted in Figure 3.

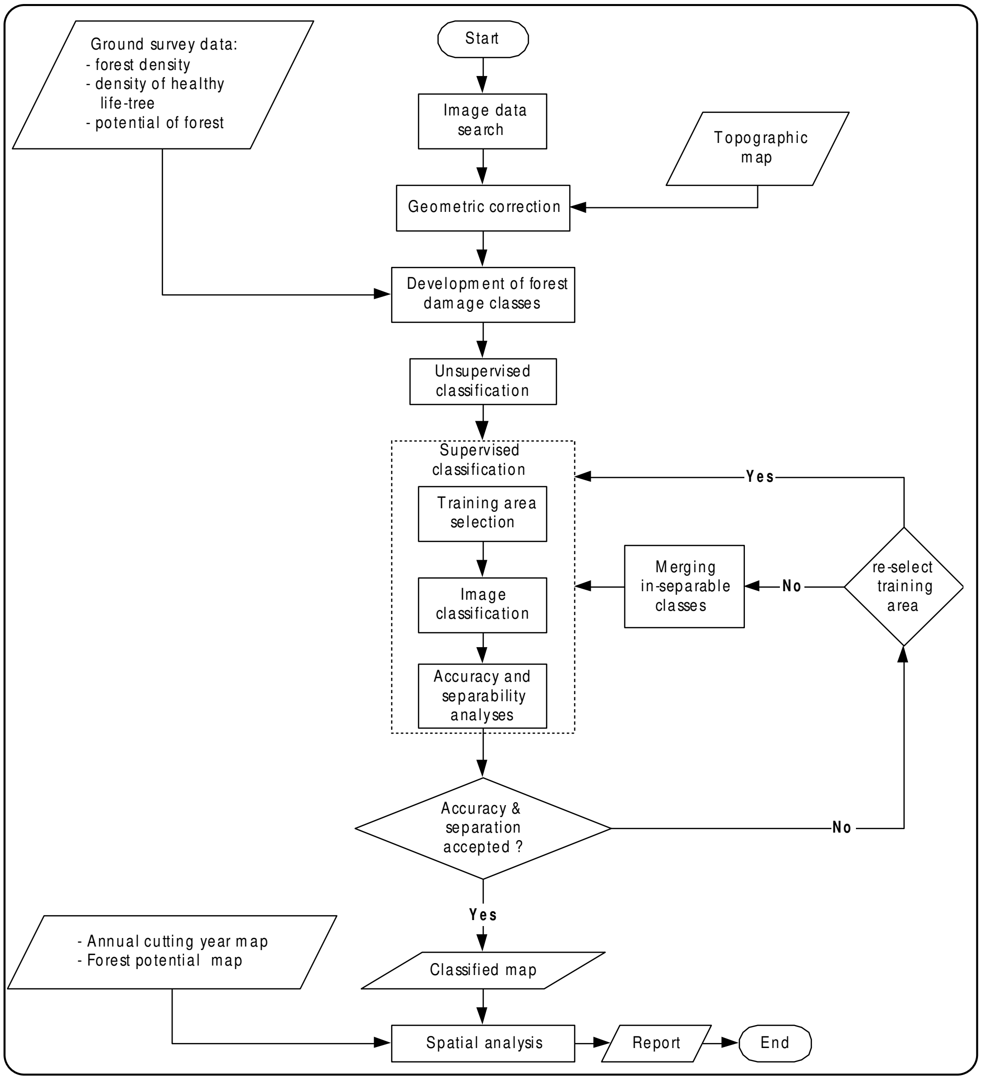

Figure 3. Flow diagram of the study

DISCUSSIONS

Feature Selection

To perform quantitative analysis, standard false color composite image of band XS3 as red, XS2 as green and XS1 as blue was created. This provides an immediate feature of post-fire condition. Through visual interpretation either on hardpaper or on computer screen, burnt and unburnt areas could be obviously discriminated. Light red colors correspond to unburnt vegetation either natural or plantation forests, while black with slightly red color shows burnt areas, mainly severely and extremely burnt forest. Since the emphasize was to discriminate the degree of forest damage digitally based on percentage of healthy life-tree, visual interpretation was performed to assist quantitative analysis especially during the selection of training area. In this study, since SPOT multispectral data have only three bands, feature evaluation was done using single band, two-band and three-band combinations. Of all possible combination evaluated, the study found that the best accuracy and inter-class separability were provided but using three-band combinations, i.e., band “XS1” (0.5 to 0.59 μm green), band “XS2” (0.61 to 0.68 μm, red) and band “XS3” (0.7 to 0.89, near infra red). As proved by Jaya and Kobayashi (1995), band combination using visible and infrared bands was recognized to be useful for detecting biomes or vegetation changes. Green band was expected to provide valuable information on green reflectance of healthy vegetation. Red band that corresponds to chlorophyll absorption of healthy green vegetation biomass present in a scene. This is particularly useful for land and water discrimination (Jensen, 1986).

Statistical analysis performed to evaluate classification accuracy and inter-class separability provides a promising result. The Kappa accuracy using all shows that, the damage degrees of burnt class were classified well, providing accuracy of 95%. The inter-class separability of damage classes using full set band also showed an excellent separation, better than using two or single band combination. The study found that good classification of burnt forest could be obtained using full set band of SPOT HRV.

Forest Damage Classification

As mentioned earlier, in order to select training area, unsupervised classification using isoclass algorithm was performed. In this clustering process, 15 unidentified classes were generated. By interactive interpretation on both false color composite and clustered images, coupled with ground survey data, 10 classes from the 15 classes mentioned earlier were developed. An ancillary data and information were also used to give identity of the 10 clusters generated. Forest concession boundary map, roads map and visual interpretation data were applied to discriminate categories with high spectral overlap. Plate 1 is the classified image using supervised classification of SPOT imagery performed in this study. It is shown, that unburnt natural tropical and plantation forests were obviously discriminated from burnt forest. However, it was noted that little confusion occurred between these two classes. Some pixels of unburnt tropical forest were classified into unburnt plantation forest. Among four forest-damage classes no significant confusion