ASSESSMENT OF FOREST RECOVERY AFTER FIRE USING LANDSAT TM IMAGES AND GIS TECHNIQUES: A CASE STUDY OF MAE WONG NATIONAL PARK, THAILAND

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ABSTRACT: In the last decade, forest fire in South East Asia has drawn attention from international level. Particularly in Indonesia during 1997-1998, it has been reported that 500,000 ha of tropical forests in were destroyed in 1998. Loss of forests and effects from greenhouse gases influence the regional and global climatic systems. In Thailand, forest fire annually occurr in dry season February till May. In Thailand, half of total forest area is occupied by mixed deciduous and dry dipterocarp forests, which are affected by forest fire almost every year. Up-to-date information in term of post-fire recovery is scarce. Remote sensing, which can provide accurate information and facilitate routine observation in inaccessible areas, has not been considered to assess post-fire recovery. GIS techniques have not been applied to integrate spatio-temporal data. This study attempts to use remote sensing, GIS and field data to assess forest recovery areas after fire and investigate the relationship between the recovery and environmental conditions in both forest types.

1. INTRODUCTION

According to the data of 1998, forest area in Thailand was estimated to cover about 25% of the country area. Mixed deciduous forest and dry dipterocarp forest occupied half of the total forest area of Thailand or 70 862.22 km^2. Forest fire has annually occurred in the dry season from February to May, generally in dry dipterocarp forest, mixed deciduous forest, pine forest and plantation forest. Moreover, fires sparsely occur in evergreen forest. During 1985-1994, aerial surveys were performed to estimate burnt forest throughout the country. At least 1 600 km^2 of forest areas were annually burnt. The assessment of the burnt area were 35 351 km^2 and 7 636 km^2 in 1985 and 1994 respectively *(RFD, 1999)*.

Remote sensing and GIS have been used for assessing the burnt forest area in 1999. The forests burnt between the 8th of January to the 16th of April 1999, were assessed to be about 2 935 km^2, which is 1.91% of the remaining forest in 1995, or 0.57% of the total area of the country *(RFD, 1999)*. From the result of the mentioned study, the burnt area in 1999 was not a large area when compared with the past, because the rainy season in 1999 came earlier starting only by late March. Consequently, the intensity of fire that always occurs in April, the driest month of year, was reduced.

Generally, ground fires and surface fires are found in mixed deciduous, dry dipterocarp, pine forests and forest plantation. However, surface fire is the major type that occurs in all these forest cover types. It is very important to study the fire issue in mixed deciduous forest and dry dipterocarp forest because both types of forest occupy half of the total forest area in Thailand, and are annually affected by forest fire during dry season. Forest fires in Thailand are mainly caused by human activities, either deliberate or accidental. Many intentional fires are ignited within forest for different purposes. By carelessly handling, fire can spread to the surrounding area.

Fire has advantages to the ecosystem of forest in Thailand such as releasing nutrients from organic matter, maintaining forest types of dry dipterocarp, mixed deciduous and pine, being the cheapest tool for silviculture activities and eliminate pest and diseases Fire also affects the vegetation in negative direction. For instance, 43% of saplings in dry dipterocarp forest were dead, and the growth of sapling was decreased by 20-25% because of the effect of fire. In mixed deciduous forest, the numbers and growth of sapling and seedling were reduced. The rate of tree seedling survival is reduced and need longer time for persistence from fire.

There is a wide variety of plant adaptations, which can evolve following fire. For instance, some plants have thick bark to insulate heat of fire. Some have hard-coated seed to protect damage after fire, or have serotiny cone which is split open and disperse seed after fire pass. Deep vertical root system is one trait that the tropical Asian pine has developed. The resprouting species can sprout via dormant buds following fire season, while seedlings establish from the germination on-site seed which have survived from fire or from seeds that have dispersed to burnt area from adjacent unburnt vegetation stands. Resprouting capacity and seeder or recruiter capacity are two main types of adaptation traits that determining the regeneration pattern of the ecosystem.

Up-to-date information in term of post-fire recovery in relation to topographic factors is scarce. Besides, remote sensing, which can provide accurate information and facilitate routine observation in inaccessible areas, has not been considered for assessing post-fire recovery. The main objective of this study is to assess forest recovery after fire. Specific objectives were: to detect the burnt forest just after fire using Landsat TM image, to detect forest recovery following fire using Landsat TM image and to investigate the relationship between forest recovery and topographic factors: elevation, slope and aspect using GIS techniques, to investigate the species composition of post-fire recovery in mixed deciduous forest and deciduous dipterocarp forest, and to investigate the statistical correlation between post-fire recovery and topographic factors elevation, slope and aspect using field data collection.

2. MATERIALS AND METHODS

2.1 Study Area

Mae Wong National Park, which is located in western part of Thailand, has been selected to perform the investigation. It is an appropriate area for this research in both scientific and practical aspects. First of all, forest fires frequently occur during the dry season in this national park. Second, the major part of the national park is covered by mixed deciduous forest and dry dipterocarp forest, which is the one of the most abundant forest types in Thailand *(RFD, 1993)*. Third, this area occupies areas that are different in topography. It covers plain areas up to mountainous areas with gentle to steep slopes, and which vary in elevation and aspect. In addition, the national park is situated close to Um Phang Wildlife Sanctuary and Huai Kha Khaeng Wildlife Sanctuary, which is a World Heritage site (together with Thung Yai Naresuan Wildlife Sanctuary). This is the largest network of protected areas of Thailand that is important from an ecological point of view. Besides, this area is an original headwater source of Mae Wong River, which is the main river in Sakaekrang watershed. This river is used as water source for agriculture activities in flood plain areas. Lastly, for practical aspects, Landsat TM images, and also other ancillary information that were needed for the study, are available. Furthermore, accessibility and co-operation with the local authorities are possible.

2.2 Materials

Two Landsat Thematic Mapper images were selected to be used in this study. The first image was collected on 20/3/1999 just after fire and a second image of 3/2/2000 one year after fire. Topographic maps, scale 1:50 000, map sheets 4840I, 4840IV, 4841II and 4841III produced by Royal Thai Survey Department (RTSD), were used as base map for the sampling design, and generating a Digital Elevation Model (DEM).

2.3 Methodology

In the first step Landsat TM images were used for visual interpretation and pre-classification in order to create preliminary maps of forest burnt in 1999, and forest recovery in 2000. In the second step, sample sites were selected according to the results from first step, and ground verification was done. The next step was image processing which included image classification, accuracy assessment and change detection analysis. The comparison between spectral signatures of different important cover types such as burnt forest, unburnt forest, and recovery forest, of images from Landsat TM was performed, to see if we can detect burnt, unburnt and recovery forest using the mentioned images. Finally, GIS was conducted to investigate the relationship between post-fire recovery and the environmental factors. The research flowchart is shown in Figure 1. Fieldwork was carried out during August - September 2000. Line transect samplings were performed in both forest types. Based on image appearance, reference data, reconnaissance survey, and fieldwork data, training sample sets were proportionally selected from Landsat TM images 1999 and 2000. The images were classified by using Supervised Classification technique and Maximum Likelihood Classifier.

3. RESULTS AND DISCUSSIONS

The Landsat TM image 1999 was classified to three classes: burnt forest, unburnt forest and bare soil. The burnt areas cover 55% or 27 311 ha of the study area. The unburnt forests cover 36% or 18 203 ha of the total area, and bare soil cover 8% or 3 997 ha. Landsat TM image 2000 was classified to three classes; post-fire recovery forest, unburnt forest and bare soil. The recovery areas cover 48% or 23 986 ha of the study area. The unburnt forests cover 41% or 20 260 ha of the total area, while bare soil cover 10% or 5265 ha.

Using the confusion matrix that resulted from the classification of Landsat TM image 1999, an overall accuracy of 94% was achieved for this classification. The average accuracy per class and average reliability per class were 94% and 92% respectively. Accuracy and reliability of burnt forest class were 94% and 93 % respectively. Unburnt forest class had the highest figure, while bare soil class had the lowest figure, in both accuracy and reliability.

Using the confusion matrix resulting from classification of Landsat TM image 2000, an overall accuracy of 83% was achieved for this classification. The average accuracy per class and average reliability per class were 87% and 80% respectively. Accuracy and reliability of recovery forest class were 74% and 88% respectively. The reliability of recovery forest class was the highest, while bare soil class had the lowest figure.

The results of image classification of 1999 and 2000 were used to detect changes between the year 1999 and 2000. These two classification maps were crossed with each other. The burnt forest area in 1999 (55 % of total area) was categorized as: no recovery 3% (1 816 ha), moderate recovery 42% (20 874 ha) and high recovery 9% (4 621 ha). The rest of the areas were unburnt forest, degraded forest and bare soil, which in total was 45% (22 200 ha). Figure 2 shows the post-fire recovery classes map resulted from change detection map of the two classification maps of 1999 and 2000.

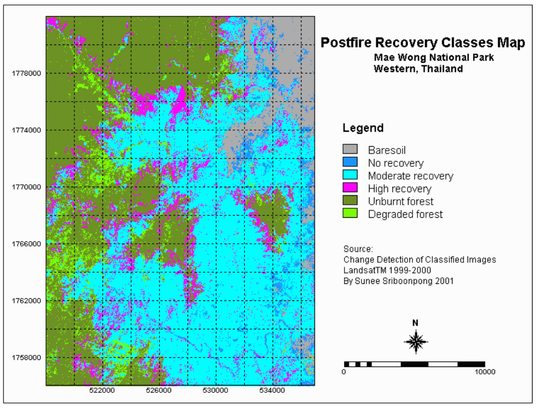

Figure 2. Post-fire recovery map

The training sample sets of pixels were selected from linear stretched images of 1999 and 2000. In order to build the coincident spectral plots, the statistic parameters, means and standard deviations of all classes in each spectral band were calculated (Figure 3 and 4). The results of the data set obtained from the image of 1999 show that all three land cover classes can be totally separated from each other in Landsat TM bands 1, 2, and 3. In band 4, there is an overlap between unburnt forest class and bare soil class, while the burnt forest class was totally separated from those two classes. This happened because some samples of bare soil class were selected in agriculture fields, which have some crop covering. As a result, these pixels yield higher spectral reflectance in band 4 (Near Infrared) than those pixels that were selected from area without any crop covering. Thus the mean and standard deviation of bare soil class in this band are higher, causing the spectral signature to overlap with unburnt forest class. The results of data set obtained from the image of 2000 show that all three classes can not be totally separated from each other in all seven spectral bands, particularly recovery forest and unburnt forest classes. However, in bands 1, 3, and 6, bare soil class can be totally separated from the other two classes, while recovery and unburnt classes have very small amount of overlapping.

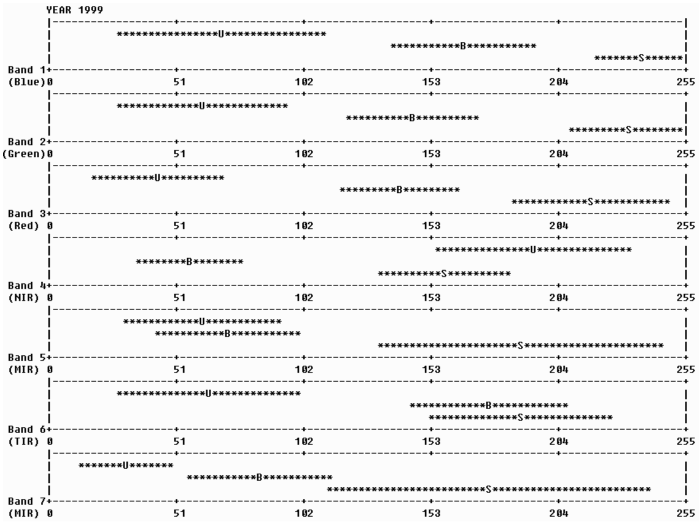

Figure 3. Coincident spectral plots for training sample sets obtained in 7 bands for three cover types in image classification of 1999 (U: Unburnt Forest, B: Burnt Forest, S: Bare soil, and one asterisk ≈ 2.55)

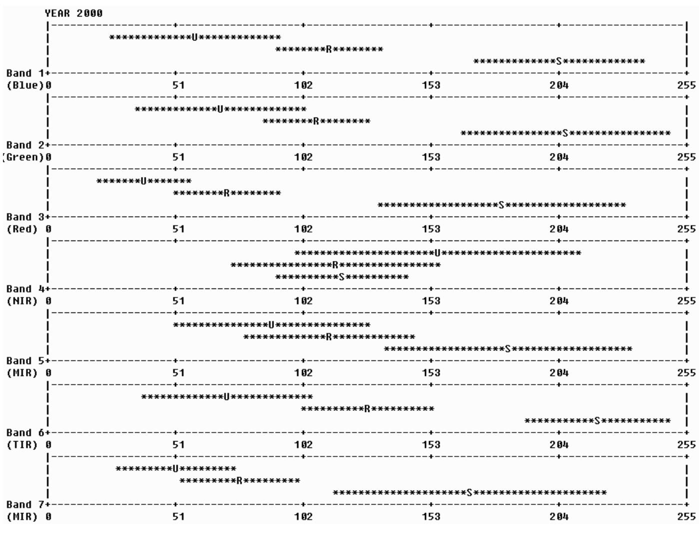

Figure 4. Coincident spectral plots for training sample sets obtained in 7 bands for three cover types in image classification of 2000 (U: Unburnt Forest, R: Recovery Forest, S: Bare soil, and one asterisk ≈ 2.55)

3.1 Results and Conclusions Remarks

The burnt forest areas can be detected by using Landsat TM image. In this study, the color composite image of 1999 combination 453 RGB shows the best result to detect the burnt forest areas. All 7 spectral bands were used in Supervised Classification with Maximum Likelihood Classifier. The classified image consists of three land cover classes: burnt forest, unburnt forest and bare soil. The overall accuracy of classification is 94%, and the reliability of burnt forest class is 93%. The post-fire recovery areas can be detected by using Landsat TM image. In this study, the color composite image of 2000 combination 453 in RGB shows the best result to differentiate recovery forest areas. All 7 spectral bands were used in Supervised Classification with Maximum Likelihood Classifier. The classified image consists of three land cover classes: recovery forest, unburnt forest and bare soil. The overall accuracy of classification is 83%, and the reliability of recovery forest class is 88%.

There is no distinct relationship between the area proportions of the no recovery class and elevation and slope variables (r^2 = 0.38 and 0.35 respectively). The proportions of the moderate recovery class tend to decrease when elevations and slopes increase (r^2 = 0.88 and 0.95). The proportions of high recovery class tend to increase when elevations and slopes increase (r^2 = 0.97 and 0.95). There is no distinct difference in the proportions of no recovery class from north, northeast, east, southeast, to south aspects. The proportions tend to decrease from southwest, west, to northwestern aspects. There is no distinct difference in the proportions of moderate recovery class in respect of any aspects. There is no distinct difference in the proportions of high recovery class from north, northeast, east, southeast, to southern aspects. The proportions tend to increase from southwest, west, to northwest aspects.

The spectral signatures of burnt forest areas are totally separated from unburnt forest and bare soil in spectral bands 1, 2, 3, and 4. The spectral signature of burnt forest in band 7 also shows a high ability to be separated from the other land cover classes. There is no totally separated spectral signature of recovery forest from other classes in all 7 bands. The signatures in bands 1, 6, and 3 show higher tendency to be separated from other classes than bands 2, 4, 5, and 7.

The difference between NDVI images of 1999 and 2000 can be used to investigate the relationship between post-fire recovery and topographic factors. There is a weak negative association between means of Difference NDVI and elevation variable (r^2 = 0.51). The relationship between the means and slope variable shows a fairly strong positive association (r^2 = 0.72). The means of Difference NDVI tend to increase from north, northeast, east, to southeast aspects, and decreases gradually from south, southwest west, to northwest aspects.

In mixed deciduous forest, only the relationship between numbers of sprouting and slope variable shows a fairly strong negative association (r^2 = 0.82). Using average field data, the number of sprouting tend to decrease when slope increases. There is no distinct statistical correlation between numbers of sprouting and elevation, numbers of seedling and elevation, numbers of seedling and slope, numbers of sprouting and aspect, and numbers of seedling and aspect. In dry dipterocarp forest, there is no distinct statistical correlation in any relationship between numbers of sprouting and seedling and topographic factors: elevation, slope and aspect.

In summary, remotely sensed data from Landsat TM sensor has shown a high potential to provide reasonably accurate information and facilitate routine observation in remote forest areas in order to detect burnt forests and post-fire recovery forests. By applying GIS technique with ancillary data, the relationship between post-fire recovery and topographic factors can be investigated. The results can be used to support decision making in forest management plan particularly in term of spatial data. Furthermore, field data also play an important role in helping to better understand the vegetation response following fire in a specific ecosystem. These data should be complemented with the results of remote sensing and GIS applications.

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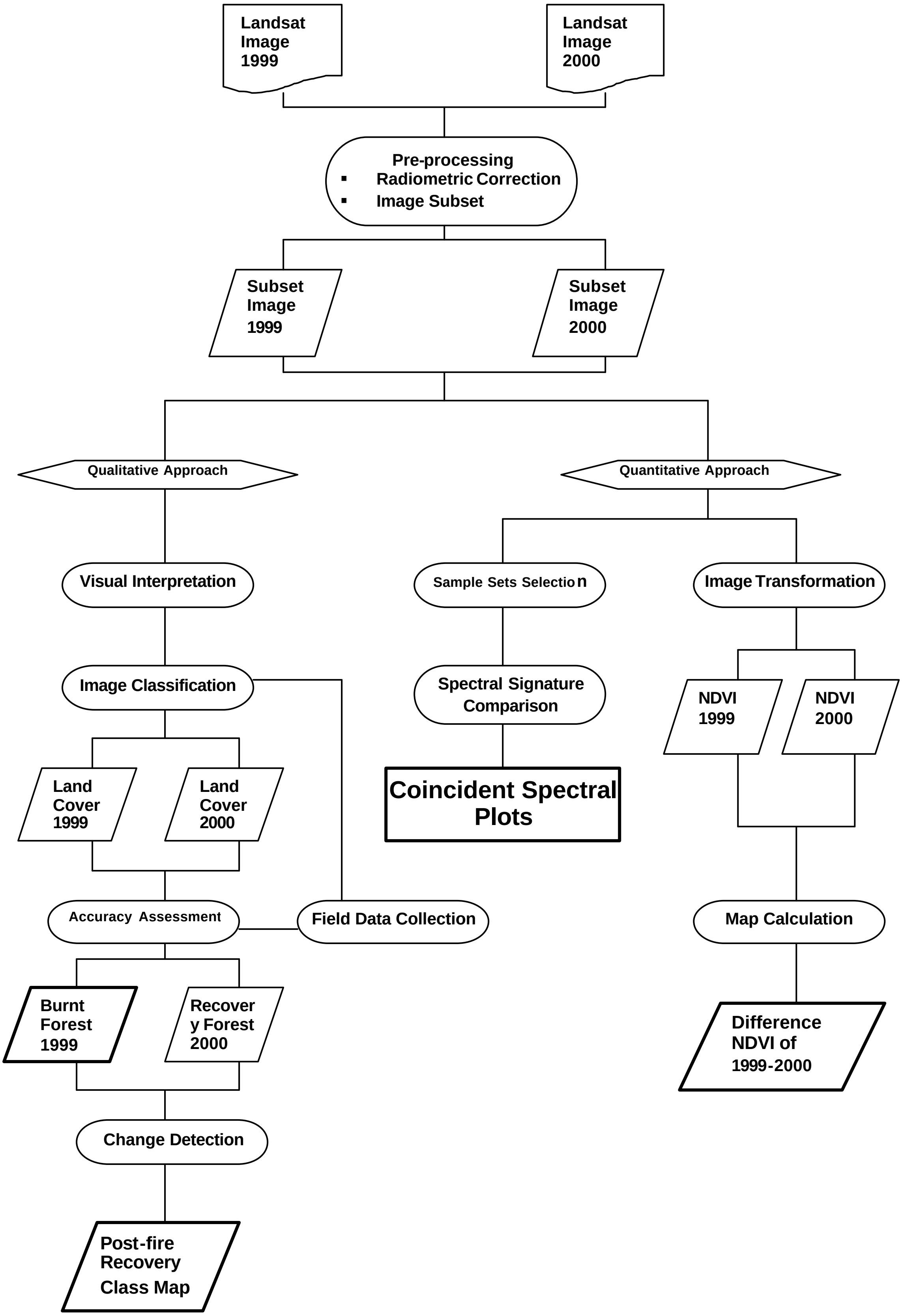

Figure 1. Methodology flowchart