Ministry of Environmental
Conservation and Forestry
Forest Department
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Assessment of forest cover dynamics and their driving forces in Kabaung Reserved Forest using remote sensing and GIS

By

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February 2012

အဝေးမှစူးစမ်းလေ့လာခြင်းနှင့် ပထဝီသတင်းအချက်အလက်စနစ်ကိုအသုံးပြု၍ ခပေါင်းကြိုးဝိုင်း၏ သစ်တောဖုံးလွှမ်းမှု ပြောင်းလဲခြင်းနှင့် ပြောင်းလဲမှုဖြစ်စေသည့် အကြောင်းရင်းများအား ဆန်းစစ်လေ့လာခြင်း

ဒေါက်တာရိုစီနေဝင်း
ဦးစီးအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

ဤစာတမ်းသည် ရွေးချယ်ခုတ်လှဲခြင်းစနစ်ဖြင့် သစ်ထုတ်လျက်ရှိသော ခပေါင်းကြိုးဝိုင်းတွင် သစ်တောဖုံးလွှမ်းမှု ပြောင်းလဲခြင်းကို အဓိကဖြစ်စေသည့် အကြောင်းရင်းများကို လေ့လာဆန်းစစ်ထားပါသည်။ ၁၉၈၉ခုနှစ် ဇန်နဝါရီလ၊ ၂၀၀၀ ခုနှစ် နိုဝင်ဘာလနှင့် ၂၀၀၃ခုနှစ် ဇန်နဝါရီလတွင် ရိုက်ယူထားသည့်ကောင်းကင်ဓာတ်ပုံများအား အသုံးပြု၍ သစ်တောဖုံးလွှမ်းမှု ပြောင်းလဲခြင်းကို သုံးသပ်တင်ပြထားပါသည်။ ဤလေ့လာမှုတွင် ရွေးချယ်ခုတ်လှဲထားသောနေရာများကို ခန့်မှန်းသိရှိနိုင်ရန်အတွက် supervised classification နှင့် normalized difference vegetation index (NDVI)ခြားနားခြင်း နည်းစနစ်များကို ပေါင်းစပ်အသုံးပြုထားပါသည်။ ခပေါင်းကြိုးဝိုင်းအတွင်း သစ်တောများပြောင်းလဲပျံ့နှံ့မှုပုံစံကို လေ့လာဆန်းစစ်ချက်အရ ရွေးချယ်ခုတ်လှဲခြင်း၊ ခပေါင်းဆည်ဆောက်လုပ်ခြင်း၊ ရွှေ့ပြောင်းတောင်ယာပြုလုပ်ခြင်းနှင့် ကျွန်းစိုက်ခင်းတည်ထောင်ခြင်းများသည် သစ်တော ဖုံးလွှမ်းမှုကို ပြောင်းလဲစေသော အဓိက အကြောင်းရင်း (၄)ခုဖြစ်ကြောင်းတွေ့ရှိရပါသည်။ အဆိုပါအကြောင်းရင်း (၄)ခုအနက် ခပေါင်းဆည်မဆောက်လုပ်မီ အလွန်အမင်းသစ်ခုတ်လှဲခြင်းသည် သစ်တောပြုန်းတီးခြင်းကို ဖြစ်စေသောအဓိကအကြောင်းရင်းဖြစ်ပါသည်။ တရားမဝင် သစ်ထုတ်ခြင်းသည် သစ်ထုတ်လမ်းနှင့်နီးသော အကွက်များတွင် သစ်တောဖုံးလွှမ်းမှုကို ပြောင်းလဲစေသည့် အဓိက အကြောင်းရင်း ဖြစ်ကြောင်းခန့်မှန်းသိရှိရပါသည်။ ဤစာတမ်းအရ သစ်တော ပြုန်းတီးမှု ကာကွယ်ရန်နှင့် အနာဂတ်သစ်တောများ ဖွံ့ဖြိုးတိုးတက်စေရန်အတွက် ခပေါင်းကြိုးဝိုင်းအတွင်း သစ်တောများဖုံးလွှမ်းမှု ပြောင်းလဲခြင်း အခြေအနေအား စဉ်ဆက်မပြတ် လေ့လာဆန်းစစ် သုံးသပ်သင့်ပါကြောင်း တင်ပြအပ်ပါသည်။

Assessment of forest cover dynamics and their driving forces in Kabaung Reserved Forest using remote sensing and GIS

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Abstract

This study examined the main factors affecting forest cover changes in Kabaung Reserved Forest, where selective logging has been carried out. Change detection was performed based on analysis of Landsat images taken in January 1989, November 2000, and January 2003. We used a combination of supervised classification and normalized difference vegetation index (NDVI) image-differencing methods to detect the selective logging area; a chi-square test confirmed the effectiveness of this method. Analysis of the spatial distribution pattern of forest cover changes pointed to selective logging, dam construction, shifting cultivation, and teak plantations as the factors influencing forest cover changes in the logging compartments. Illegal logging was a possible process of forest cover change in easily accessible non-logging compartments. Regarding deforestation, intensive felling before dam construction was the main one among the above four factors. This study suggests the need for further development of regular assessment and monitoring of forest cover changes in the Kabaung Reserved Forest to examine and protect against forest reduction.

Contents

Assessment of forest cover dynamics and their driving forces in Kabaung Reserved Forest using remote sensing and GIS

1. Introduction

Although Myanmar has a long history of forest management, including scientifically based approaches, the country currently faces problems of forest degradation and deforestation. The Food and Agriculture Organization (FAO) estimated that 466,000 ha of forested area in Myanmar were destroyed annually between 2000 and 2005 (FAO 2006). However, very few empirical studies have been carried out to ascertain the main cause of deforestation.

Susana and Mario (2000) used Landsat satellite images to study deforestation rates and land use changes related to environmental factors in Chiapas, Mexico. Phong (2004) also used Landsat imagery but with different change-detection techniques to analyze forest cover dynamics and deforestation in a national park of Vietnam. Information on changes in land use and forest cover plays a key role in current strategies for managing natural forests and monitoring their environmental change. Understanding the processes and causes of forest cover change will help resource managers and policymakers to decide where action should be taken and what kind of intervention is needed. Thus, this paper sought to detect forest cover changes and their causes in natural teak bearing forests under selective logging operations in the Bago Mountains from 1989 to 2003 by using a combination of field observations, interviews, logging records, and satellite image analysis to contribute to sustainable forest management of the area.

2. Materials and methods

Remote Sensing and Geographic Information System (GIS)

Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand & Kiefer, 1994). Information is derived from the image data, which form a (limited) representation of the real world (Janssen & Huurneman, 2001). Remote sensing relies on the measurement of electromagnetic energy, which can be the sunlight or can be created by sensors (active remote sensing). The energy source transmits to the ground surface and will partly be reflected to the sensor. The reflectance of the electromagnetic energy will then be stored as a digital image, which can be received by the ground receiving stations. In the ground receiving station, some preliminary steps of image processing will be taken place. The users hence can use the remotely sensed data with different level of pre-processing to carry out further image processing in order to create the information that are suitable for their specific purpose. Due to the fast development of remote sensing technology over the last decades, land cover maps can be established more precisely. Hence, application of remote sensing technology for land cover mapping is widely used. There are many kinds of remotely sensed data such as aerial photographs, optical satellite images such as LANDSAT and SPOT, radar images and non imaging data.

GIS stands for geographic information system. It is a computerized system that helps in maintaining data on geographic space. In the wider sense, a GIS consists of software, data, people and an organization in which it functions. A GIS always consists of modules for input, storage, analysis display and output of spatial data (de By 2001). GIS technology is used for making forest and socio-economic maps. On the other hand, the modeling capabilities of the GIS have been used for analyzing natural resources issues (Mallawaarachchi et al. 1996). The geographic information system is actually very complex and varied according to the needs and objectives of the users. The power of GIS has been widely recognized in all fields of normal life that used geographical information, in resources management, land use planning, transportation, marketing and many other applications. A large number of natural resources management and planning are now using GIS, and the handling of spatial data of all types by computer is widespread (Graem, 1994). Professionals in every field are increasingly aware of the advantages of thinking and working geographically. The spatial data can be assessed, transformed and manipulated interactively in GIS. GIS are used to perform Geographic Queries and Analysis, improve organizational integration, and make better decisions and making maps. Map making and geographic analysis are not new but a GIS performs these tasks better and faster than the old manual methods do. Arronoff, S. (1994) has pointed out the power of the system is most apparent when the quality of data involved is too large to be handled manually.

Satellite remote sensing data has been importantly substantial and extensively used to map forests of tropics. The integration of remotely sensed data with digital geographical data could be time and cost effective method of forest mapping and proper planning of resource in natural resource management (Gartner and Genderen 1996). Remote sensing techniques have ability to grasp up data rapidly and inexpensively over large geographic regions. It is comprehensively useful for conservation biologist and environmentalists for mapping natural resources, monitoring the local, regional and global changes in environment (Wilkie and Finn,1996). Therefore, remote sensing was one of the important techniques which can provide the information essential for developing strategies of intervention program to mitigate adverse impacts on natural resources. Remote sensing data will be classified or analyzed with other geographic data to obtain a higher accuracy of classification. Remotely sensed data integration with GIS model is very useful for studies of natural resources phenomena with respect to various environmental/ biophysical factors.

Normalized Difference Vegetation Index (NDVI)

NDVI stands for Normalized Difference Vegetation Index. NDVI is the most widely used of all vegetation indices and it can be applied to all multi-spectral data types. NDVI has been demonstrated to be well suited for monitoring broadleaf forest condition and for many other applications (Lunetta and Elvidge, 1999), and is least affected by topographic features (Lyon et al., 1998). It is a calculation of the photosynthetic output in a pixel within a satellite image. It measures the amount of green vegetation in the image. NDVI calculations are based on the principle that growing plants strongly absorb radiation in the visible region of the spectrum, while strongly reflecting radiation in the near-infrared (NIR) region. The magnitude of NDVI is related to the level of photosynthesis activity in the observed vegetation. It is calculated by using two biologically meaningful bands of the electromagnetic spectrum, near infrared and red. Healthy vegetation absorbs most of the visible light (from 0.4 to 0.7μm) that hits it, and reflects a large portion of the near-infrared light (from 0.7 to 1.1μm). Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. This is in contrast to other surfaces on the earth like water and bare soils where there is no significant difference between reflectance in the visible and the near-infrared areas.

In general, if there is much more reflected radiation in near-infrared wavelengths than in visible wavelengths, then the vegetation in that area is likely to be dense or may contain some type of forest. If there is very little difference between the reflectance of near-infrared and visible wavelengths, then the vegetation is probably sparse and may consist of grassland or desert. NDVI is defined as the difference between the visible (red) and near-infrared (NIR) bands, over their sum. The equation is

$$NDVI = (NIR - Red)/ (NIR + Red)$$

NDVI value ranges from -1 to +1. Healthy vegetation has high NDVI values between 0.1 and 1 because of high reflectance in the NIR portion of the electromagnetic spectrum (EMS). On the contrary, non-vegetated surfaces such as water bodies give negative values of NDVI because of the electromagnetic absorption quality of water. NDVI values close to zero in bare soil areas due to high reflectance in both the visible and NIR portions of the EMS (Lillesand and Kiefer, 1994).

As the NDVI correlates directly with vegetation productivity, there are numerous possible applications of this index for ecological purposes. NDVI provides information about the spatial and temporal distribution of vegetation communities, vegetation biomass and the extent of land degradation in various ecosystems.

Satellite images

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images for January 1989, November 2000, and January 2003, and logging records (including logging year, logging compartment, number of extracted trees, total volume of extracted trees, and species name) from 1996 to 2002 were used to assess forest cover changes. The spectral signature is not much different between the image from November (end of wet season) and January (end of the cold period of the dry season). According to the field survey, a few leaves start shedding in January, but most trees retain their leaves in the study area.

Table 1 Data sets used for assessment of forest cover changes of the study

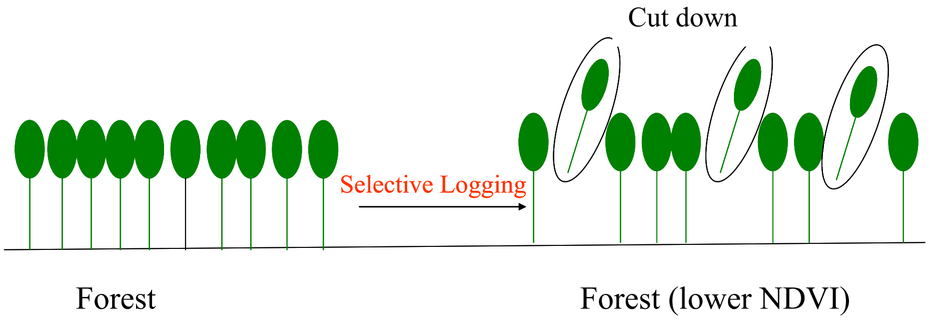
No	Year	Satellite	Spatial Resolution	Acquisition Date
1	1989	Landsat TM	30m x 30m	16.1.1989
1	2000	ETM+	30m x 30m	14.11.2000
2	2003	ETM+	30m x 30m	23.1.2003

Classification of the satellite images

The three satellite images were geo-referenced to the Universal Transverse Mercator (UTM) and World Geodetic System 1984 (WGS-84) coordinate systems. Training sites for forest cover in 1989, 2000, and 2003 were selected based on a field survey, interviews with villagers, and information from the Forest Department. In addition to field data, shifting cultivation plots were extracted from each corresponding satellite image using the normalized difference vegetation index (NDVI) (Rosy Ne Win 2008) and used for training sites. To identify shifting cultivation plots, the area, shape, and chronological change in plant cover were taken into consideration. Plots much smaller or larger than the sizes of actual shifting cultivation plots obtained from the field survey were excluded. Areas having NDVI values lower than the threshold value for several consecutive years were determined as "other" areas (such as settlements, roads, permanent agriculture) and also excluded. Image classification was made in ERDAS IMAGINE using the supervised classification technique with the maximum likelihood algorithm. In the supervised classification, the study area was divided into four forest cover classes: "*Forest*," "*Degraded Forest (Bamboo)*," "*Bare and Grassland*," and "*Water Body*."

NDVI image differencing

In addition to the four forest cover classes created by supervised classification, the area affected by selective logging should be considered in the forest cover change analysis. Numerous methods have been used for detection of selective logging. According to Souza et al. (2005), the first technique for detecting an area of selective logging was visual interpretation of Landsat images; however, this method is challenging when the logging intensity is low, and it can be susceptible to human bias. Landsat reflectance data and texture analysis have also been used to map selective logging (Asner et al. 2002), but this method is prone to error caused by spectral ambiguity between selectively logged areas of various ages and extraction intensities (Souza et al. 2005). Several approaches such as maximum likelihood classification, subpixel classification, vegetation indices [e.g., the modified soil adjusted vegetation index (MSAVI), soil adjusted vegetation index (SAVI), and NDVI], and forest canopy density (FCD) mapping have been tested to detect the selective logging area (Bhandari 2003). Only subpixel classification and MSAVI gave reasonable results. In our study, most of the selective logging area could be classified as *Forest* because the felling of selected trees meeting exploitable dbh limits causes little change in canopy density. To overcome these problems, many studies have applied a combination of methods, e.g., a combination of a decision tree classifier (DTC) and fraction images (Souza et al. 2003) or of a normalized difference fraction index (NDFI) and a contextual classification algorithm (CCA) classifier (Souza et al 2005). However, an optimal method for detecting selective logging has not yet been developed. In this study, we applied a combination of supervised classification and NDVI image differencing for detecting the selective logging areas because, in an area of selective logging, the NDVI value decreases even though the area can still be classified as *Forest*.



For the NDVI image-differencing method, radiometric quality adjustment was performed to mitigate differences in spectral reflectance properties among the three images. The image from 2000 was selected as the reference image to adjust the 1989 and 2003 images. The control set for radiometric adjustment was selected from the protected forest, which had similar surface reflectance properties in the images from different dates. Radiation quality adjustment for band 3 and band 4 of the 1989 and 2003 images was conducted. The NDVI was then calculated for all three images as

$$\text{NDVI} = (\text{band } 4 - \text{band } 3)/(\text{band } 4 + \text{band } 3).$$

From two NDVI images, approximately 100 pixels were chosen from the protected forest area, and the NDVI change value for each pixel was calculated. The mean and standard deviation (SD) for the NDVI change value of 100 pixels were determined.

Then, the NDVI change image (1989-2000 or 2000-2003) was classified into three categories: positive change (greater than mean ± SD of protected forest), no change (mean value ± SD of protected forest), and negative change (less than the mean value ± SD of protected forest). The *Extraction Area* (EA) is included in the negative change category because we defined an EA as the area in which the land class was classified as *Forest* in two satellite images but the NDVI was lower in the later image. Most of the selective logging area was expected to be included in the EA. Figure 1 shows the flow chart for preparation of NDVI image differencing.

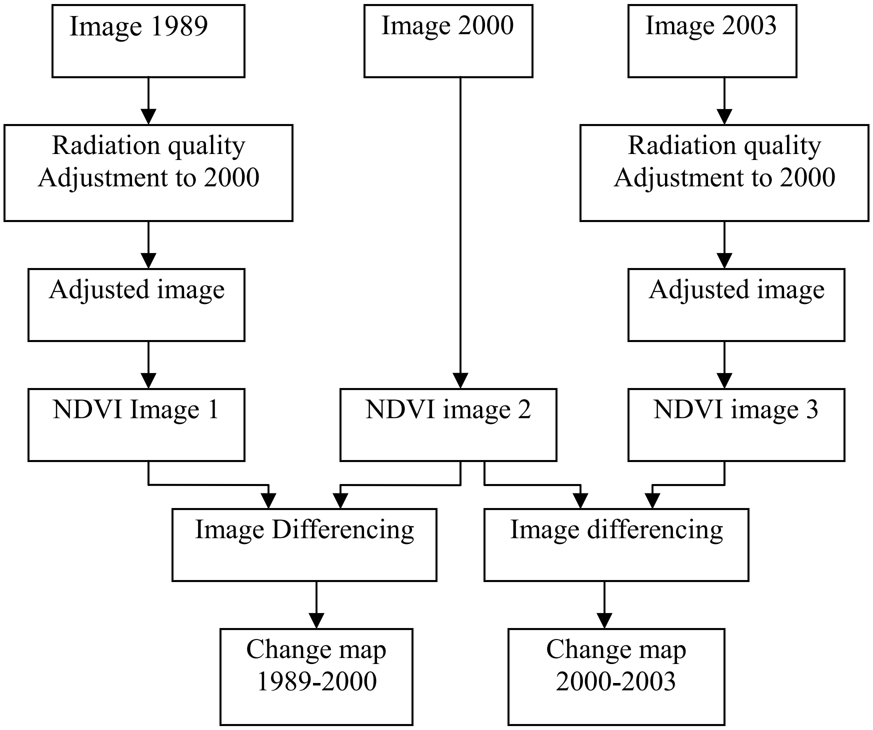


Fig. 1 NDVI image differencing change detection

Preparation of maps of forest cover change

The forest cover change maps were generated using a combination of NDVI change maps and classified images created by supervised classification (Figure 2). To assess the accuracy of the image classification, Kappa statistics were calculated. Global Positioning System (GPS) points for each forest cover identified in the field survey and in interviews with local community members and staff of the Forest Department were used in the accuracy assessment. First, an error matrix was created, and the overall accuracy and Kappa were calculated.

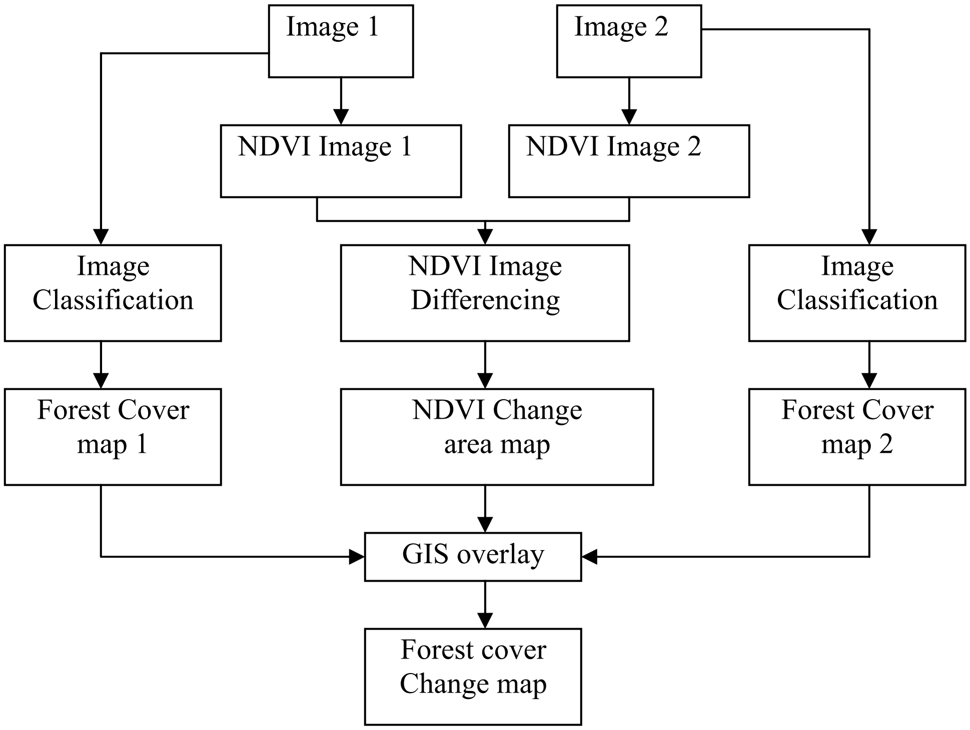


Fig. 2 Flow chart of the preparation of the forest cover change map preparation

Regrouping the forest cover changes

After preparing the forest cover change maps, we calculated the area changes from one forest cover class to another. Not all changes were taken into account; changes from water to other forest cover classes and from other forest cover classes to water were not considered, as the change in area was quite small. Seven changes that were analyzed for forest cover change assessment were regrouped into two categories, namely, “Forest Loss” and “Forest Gain.” *Forest* to *Extraction Area* (F to EA), *Forest* to *Degraded Forest* (F to DF), *Forest* to *Bare and Grassland* (F to BG), and *Degraded Forest* to *Bare and Grassland* (DF to BG) were regarded as

Forest Loss. *Degraded Forest* to *Forest* (DF to F), *Bare and Grassland* to *Forest* (BG to F), and *Bare and Grassland* to *Degraded Forest* (BG to DF) were defined as Forest Gain.

Forest cover change analysis

To determine suitable classes for each forest cover change, the deviation value (DV) was calculated by the following equation:

$$\text{Deviation value} = 10(a - \bar{a})/SD + 50,$$

where a = forest cover percentage change of each compartment, $\bar{a}$ = mean forest cover percentage change of the total of all compartments, and SD = standard deviation.

The concept of the deviation value is identical to that of normalization. The mean value of 0 corresponds to that of 50, and the standard deviation of 1 is replaced with 10. In this study, the ranges of percentages of forest cover change differed considerably (i.e., the change percentages of DF to BG and of F to BG were much lower than were those of other changes). Here, we used the deviation value to adjust the forest cover change data and selected the most suitable class of deviation value that was uniform in two periods. Depending on the data in the two forest cover change maps, deviation value categories of <60, 60-70, and >70 are the best for clearly showing the forest cover changes (Figures 2.8, 2.9, and 2.10).

To analyze the effect of logging on forest cover change, recent annual data for logging compartments (1996-2000 for the first period and 2001-2002 for the second period) were used. These recent annual data were used because visible signals of selective logging may be evident for only a limited time due to canopy recovery. Each type of forest cover change was divided using the deviation value, and the spatial distribution pattern of each change in forest cover for both periods was then analyzed.

3. Results

Accuracy assessment

The overall accuracy of the forest cover change classification map for 1989-2000 was 78.7% (Kappa coefficient of 0.70), whereas for 2000-2003 the accuracy was 74.4% (Kappa coefficient of 0.64).

Image Classification

Figures 3 and 4 are forest cover change maps produced with the combination of NDVI change images and classified images by supervised classification method.

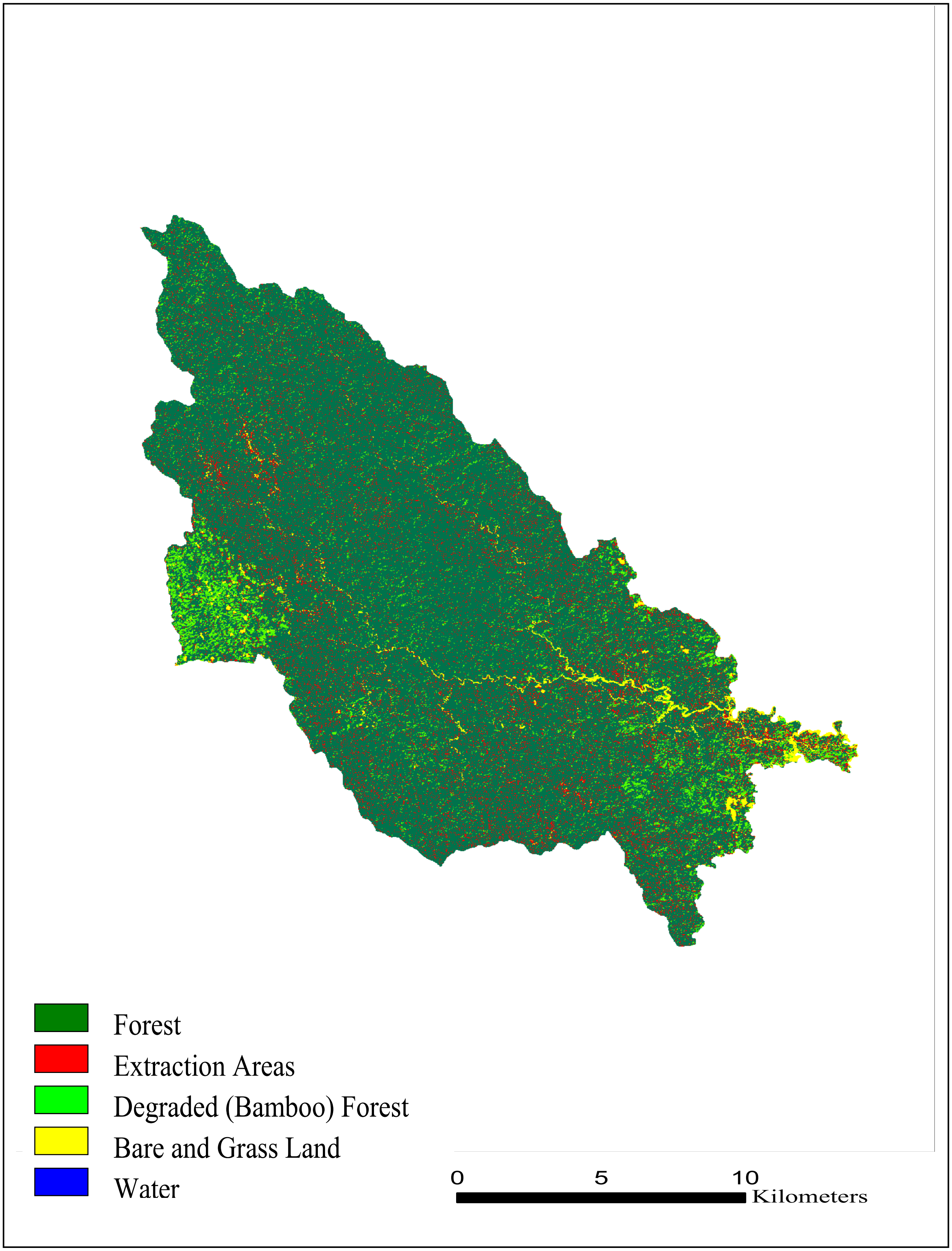


Fig. 3 Forest cover change map of the Kabaung Reserved Forest in 1989-2000

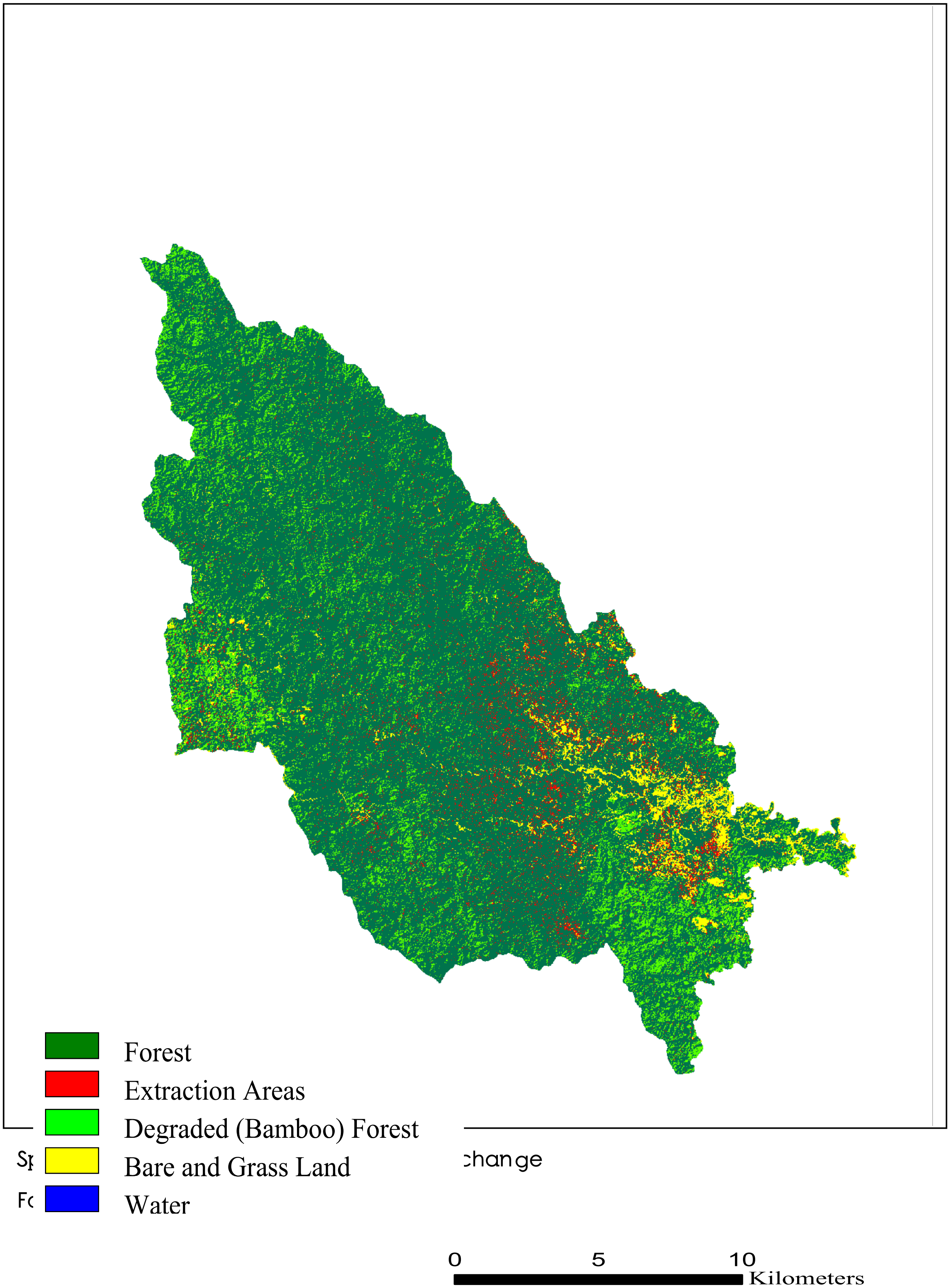
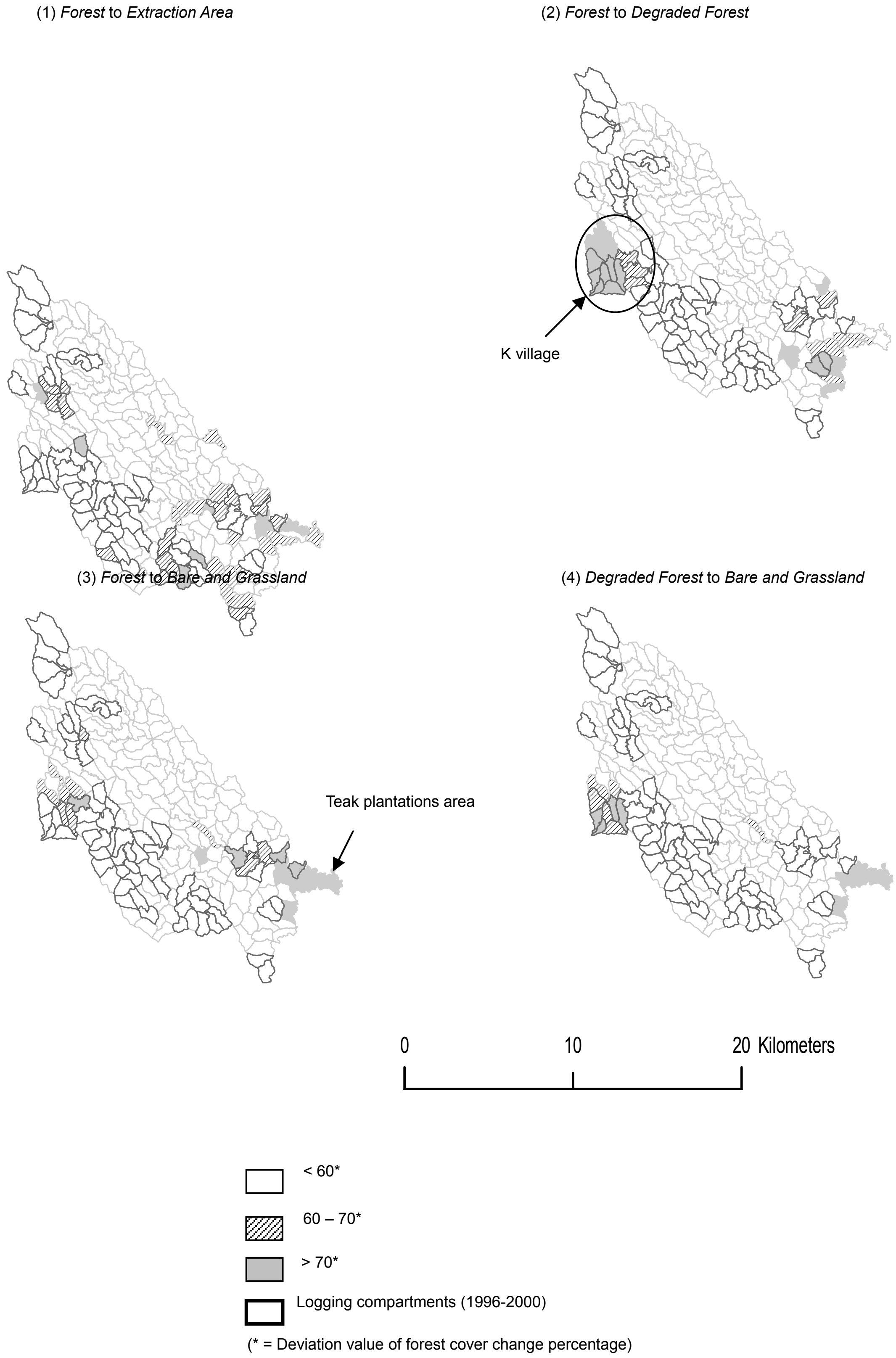


Fig. 4 Forest cover change map of the Kabaung Reserved Forest in 2000-2003



(1) *Forest* to *Extraction Area*

(2) *Forest* to *Degraded Forest*

(3) *Forest* to *Bare and Grassland*

(4) *Degraded Forest* to *Bare and Grassland*

Fig. 5 Spatial distribution pattern of each type of forest cover change in 1989-2000

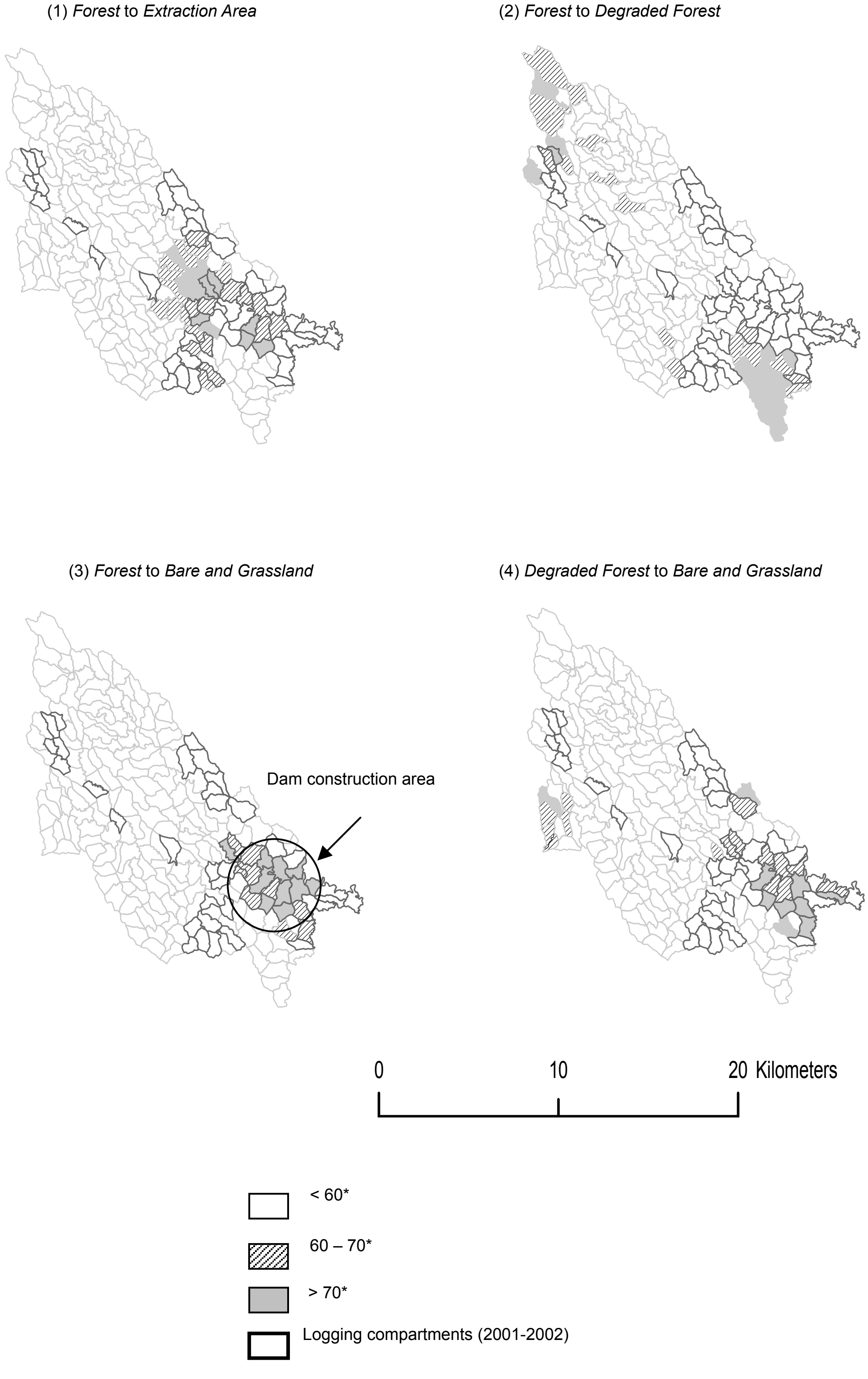


Fig. 6 Spatial distribution pattern of each type of forest cover change in 2000-2003

(i) *Forest* to *Extraction Area*

Forest loss from F to EA was observed in logging compartments as well as in non-logging compartments located near logging compartments (Figures 5 and 6).

(ii) *Forest* to *Degraded Forest*

During 1989-2000, a high percentage of F to DF was found in K village, where shifting cultivation has been practiced since colonial times, and also in some non-logging compartments (Figure 5). In 2000-2003, a high percentage of F to DF was observed in non-logging compartments near the main road and near the logging compartments (Figure 6).

(iii) *Forest* or *Degraded Forest* to *Bare and Grassland*

During 1989-2000, F to BG and DF to BG were observed in K village and in the teak plantations area where taungya teak plantations have been established by the Forest Department (Figure 5). In 2000-2003, F to BG was seen only in the dam construction area, where intensive logging was carried out in 2002. DF to BG was found in the dam and teak plantation areas and in K village (Figure 6).

The analysis of the spatial distribution pattern of forest cover changes revealed four main factors that may have contributed to these changes: logging, intensive felling due to dam construction, shifting cultivation, and taungya teak plantations.

Forest Gain

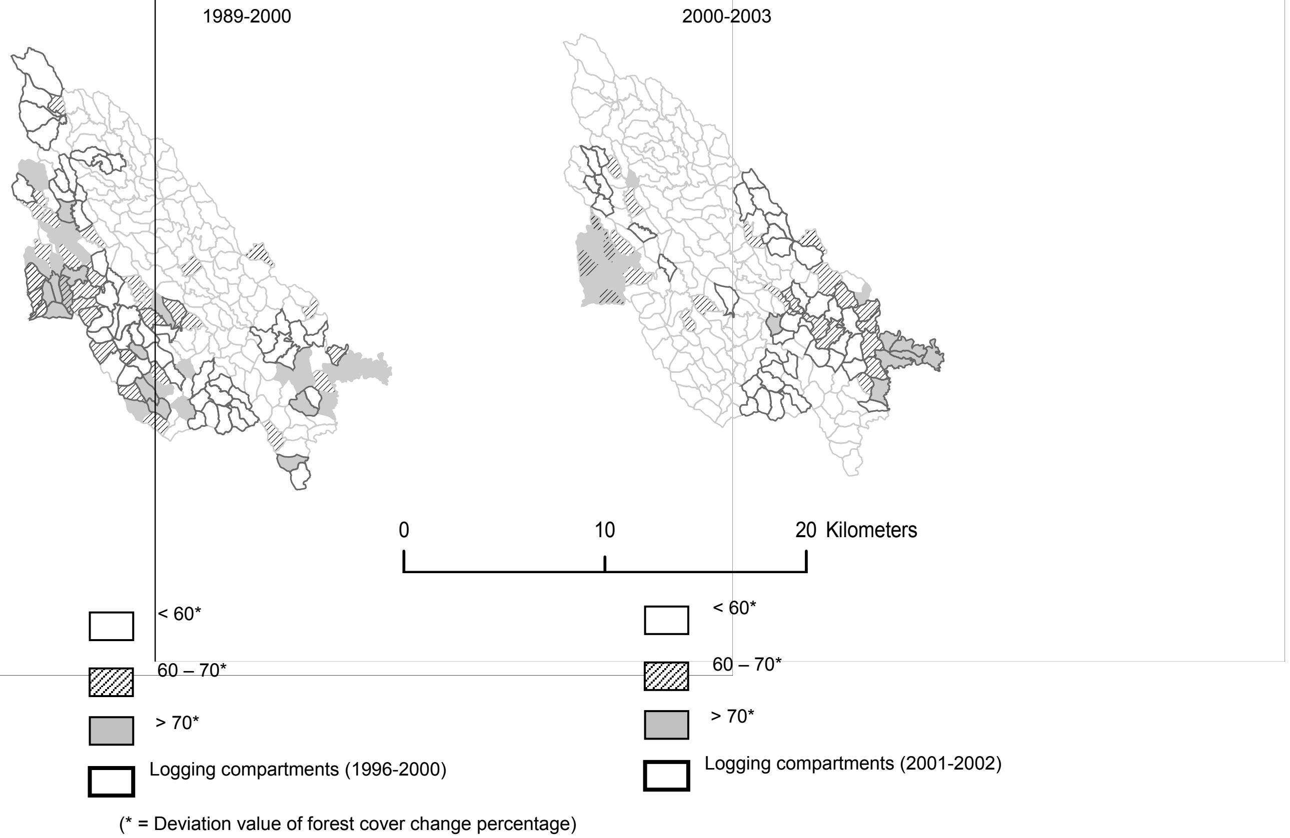


Fig. 7 Spatial distribution pattern of Forest Gain in 1989-2000 and 2000-2003

Forest Gain occurred in K village, teak plantations and in some logging and non-logging compartments during 1989-2000. During 2000-2003, Forest Gain was observed in K village, teak plantations and the dam construction area (Figure 7). However, Forest Gain was less than Forest Loss in both periods.

Analysis of the relationship between logging operations and the *Extraction Area*

Table 2 Chi-square test of the relationship between logging operations and *Extraction Area*

Factor	Extraction Area		χ^2	df	*p*-value
	<30ha	>30ha			
No. of logging compartments (1989-2000)	14(36%)	25(64%)			
No. of non-logging compartments (1989-2000)	105(58%)	75(42%)	6.503	1	0.011
No. of logging compartments (2000-2003)	40(78%)	11(22%)			
No. of non-logging compartments (2000-2003)	157(93%)	11(7%)	9.769	1	0.002

[Note* 1998-2000 and 2001-2002 logging compartments were used for the first period (1989-2000) and the second period (2000-2003) respectively].

Table 2 shows the relationship between logging operations and *Extraction Area* based on chi-square tests. For the chi-square test, EA was divided into two categories, >30 ha and <30 ha. The area of 30 ha was the estimated gap area in a logging compartment due to logging operations and was calculated using the following formula:

30 ha = (estimated crown area of a felled tree $*$ no. of extracted trees) + estimated disturbed area during the logging operation.

According to the field survey, the average crown area of a felled tree was 304 m^2. According to the logging data, the average logging intensity was three trees per ha. The average size of each compartment was about 300 ha, and the total number of extracted trees in each compartment was about 900. Disturbance by logging (damage to the remaining trees, log landings, logging roads) was estimated to affect approximately 3 ha. Therefore, 30 ha = 0.0304 ha x 900 + 3 ha.

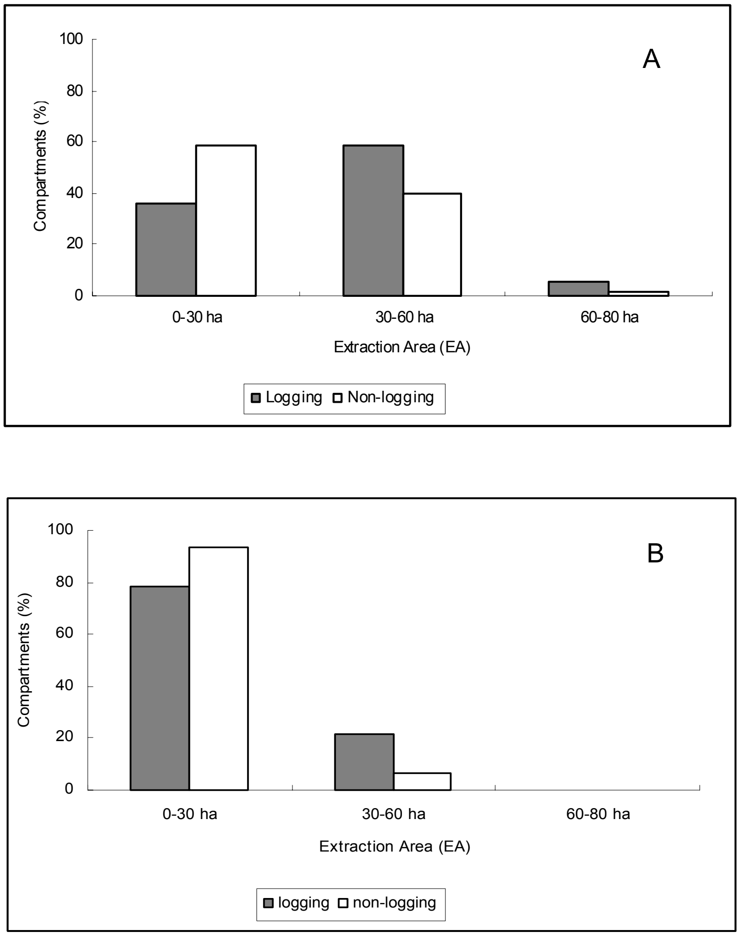


Fig. 8 The size distribution of EA in logging and non-logging compartments in (A) 1989-2000 and (B) 2000-2003

Figure 8 shows the size distribution of EA in logging and non-logging compartments. Based on the chi-square test (Table 2), the ratio of compartments having an EA of more than 30 ha was higher in logging compartments than in non-logging compartments.

4. Discussion

Relationship between logging operations and forest cover change

The main cause of F to EA was the felling of selected trees. The effect of selective logging was determined in logging compartments by examining the higher ratio of logging compartments than of non-logging compartments that had an EA >30 ha (Table 2, Figure 8 A and 8 B). From the results of this analysis, a combination of supervised classification and NDVI change detection methods was found to be suitable for detecting selective logging areas.

Assessment of the main causes of forest cover change

Effect of logging on forest cover change

Selective logging operations are the main cause of F to EA changes. The impact of selective logging on deforestation can be seen by comparing Forest Loss to Forest Gain. Change from F to DF was observed in some non-logging compartments located near the main road and near logging compartments. Zaitunah (2004) found that roads are the main factor affecting illegal logging, and the closer an area is to the road, the higher is the level of illegal logging. Logging roads make the study area easily accessible, and deforestation in non-logging compartments was detected. Illegal cutting may be the main process of the forest cover change and deforestation in non-logging compartments.

Effect of intensive felling due to the dam construction on forest cover change

In 2001, the construction of Kabaung Dam began. Because the dam would submerge some compartments, intensive logging operations were undertaken around the dam construction area prior to submersion, from 2002. Clear-cutting of forest and degraded forest areas during this operation may have caused F to BG and DF to BG changes in the dam construction area during 2000-2003. Kabaung Dam was one of the main causes of forest cover change.

Effect of shifting cultivation on forest cover change

The Karen people living in K village are allowed to practice shifting cultivation, which they have practiced since colonial times. They open a shifting cultivation area for 1 year in one place and then move to another plot the following year. The recovery process of fallow vegetation in this village is from BG to DF and then to F. In 1- and 2-year fallow lands, grasses and herbs are dominant. In 5-year fallow lands, the grasses and herbs are suppressed and bamboo becomes the dominant species. In 10-year and older lands, trees overtop the bamboo and gradually become dominant (Fukushima et al. 2007). In this study, we could not unify the analytical range of time for the first and second periods due to a lack of available satellite images. The former period (1989-2000) was 11 years and the latter period (2000-2003) was 3 years. According to the vegetation recovery process in K village, BG will recover to DF after 5 years, and F to DF was observed over the longer period (1989-2000).

From interviews with villagers, it was learned that shifting cultivators appear to prefer DF for practicing shifting cultivation because it is easy to open such areas. According to the analysis, 435 ha of DF existed in 1989, and this increased to 1048 ha in 2000 (Rosy Ne Win 2008). In 1989, not enough DF was available for shifting cultivation, and the cultivators used both F and DF. Therefore, F to BG and DF to BG were seen in the period 1989-2000 (Figure 5). In 2000, DF had increased to 1048 ha, and hence, it was used for shifting cultivation; DF to BG was only seen during 2000-2003 (Figure 6).

Effect of taungya teak plantations on forest cover change

The Forest Department established taungya teak plantations to compensate for the logged trees. As an area was clear-cut for teak plantation establishment, F to BG and DF to BG were observed in the teak plantation areas.

5. Conclusion

In this paper, a combination of supervised classification and NDVI image differencing proved to be useful for detecting selective logging areas and facilitated a more detailed assessment of deforestation. Four main factors affected forest cover changes: logging, intensive felling due to dam construction, shifting cultivation, and teak plantation establishment. This study showed that selective logging under the Myanmar Selection System did not have a severe effect on forest cover change and Forest Loss. Among the four possible factors, intensive felling before reservoir submergence was the main factor in deforestation. The impact of the construction of Kabaung Dam on forest cover change may be useful information when considering the construction of other dams in the Bago Mountains. The results can be used to increase awareness of threats to the environment and perhaps lead to timely decisions in forest conservation efforts.

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