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Deforestation in Bukit Barisan Selatan National Park, Sumatra, Indonesia

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ABSTRAK

Deforestasi di Taman Nasional Bukit Barisan Selatan, Sumatra, Indonesia. Studi ini menerangkan deforestasi dan penyebabnya di Taman Nasional Bukit Barisan Selatan (TNBBS) yang merupakan habitat bagi berbagai satwa liar yang terancam punah. Penelitian ini menghubungkan metode penginderaan jauh dengan metode wawancara untuk memperkirakan laju deforestasi dan mengetahui penyebab deforestasi. Hasil wawancara menunjukan bahwa penggundulan hutan di TNBBS di mulai sejak tahun 1960an, lebih awal dari perkiraan sebelumnya. Hasil tersebut di perkuat oleh hasil analisa citra-satelit yang menunjukan bahwa sebelum 1972 tutupan hutan seluas 46.100 ha atau sekitar 13% dari luas hutan di TNBBS telah hilang. Rata-rata laju deforestasi sejak 1972 hingga 2006 adalah 0,64% per tahun. Hanya sekitar 67.225 ha hutan yang tersisa pada 2006 dari 310.670 ha hutan pada tahun 1972, atau sekitar 22% tutupan hutan telah hilang sejak 1972 hingga 2006. Laju deforestasi di TNBBS paling tinggi di hutan perbukitan (9.01 km2/tahun), kemudian hutan dataran rendah (7.55 km^2/tahun), and hutan pegunungan (3.43 km2/tahun). Deforestasi tertinggi terjadi pada dekade pertama (1972-1985), setiap tahunnya seluas 28 km^2 hutan di babat habis, kemudian pada dekade berikutnya (1986-1996) deforestasi hanya 15 km^2/tahun, namun pada dekade terakhir deforestasi meningkat kembali (21 km2/tahun). Pelaku yang secara fisik membabat hutan di TNBBS adalah petani yang tinggal di dalam dan di sekitar hutan. Meskipun demikian, yang menjadi penyebab terpenting deforestasi di TNBBS adalah penyebab tidak langsung seperti illegal logging, Hak Pengusahaan Hutan, tingginya harga kopi, lemahnya penegakan hukum, dan situasi sosial-ekonomi di tingkat lokal dan nasional. Faktor-faktor tersebut merupakan faktor external yang mendorong petani untuk membuka hutan di TNBBS atau memperluas lahan garapannya.

Kata kunci: Deforestasi, Penyebab deforestasi, Survei wawancara, Penginderaan jauh, Taman Nasional Bukit Barisan

INTRODUCTION

Bukit Barisan Selatan National Park (BBSNP) is the third-largest protected area on the Indonesian island of Sumatra, and tropical deforestation constitutes one of the greatest threats to its conservation. The United Nations Framework Convention on Climate Change/ UNFCCC (2007) declared that the international community faces the urgent task of reducing tropical deforestation as one of a suite of measures to reduce the impacts of global climate change and to maintain biological diversity. One of many responses of conservation biologists to this threat has been to develop an array of tools for measuring and monitoring

deforestation, many of which use remotely sensed data collected by satellites (Saatchi *et al.* 2001). Satellite-based datasets can provide fine-scale measures of deforestation rates; however, many aspects of deforestation processes that are related to social phenomena (including causes of deforestation) cannot be measured using satellite sensors (Turner *et al.* 2001). Therefore, approaches that link administrative and remote-sensing data are important for understanding trends in and causes of deforestation. Most studies linking remote-sensing observations and administrative data have been undertaken at the scale of the administrative units (Wood & Skole 1998). However, Mertens *et al.* (2000) do integrate remote-sensing data and household surveys to understand the impact of macroeconomic change on deforestation processes in South Cameron.

BBSNP contains some of the largest tracts of tropical forest remaining on Sumatra and is a good example of the dramatic loss of tropical forest in Indonesia. Although BBSNP was declared a World Heritage site by UNESCO (decision 28COM 14B.5), in the past decade BBSNP's forest cover has declined dramatically. Since the early 1970s, much of the forest cover in BBSNP has been cleared, but there are conflicting estimates of the scale and rates of loss. For example, Kinnaird *et al.* (2003) found that between 1985 and 1999 the park lost more than 661 km^2 of forest (28%). On other hand, Gaveau *et al*. (2007) showed that the average rate of deforestation from 1972 to 2002 in an area of 1.17 million ha in southwest Sumatra that includes BBSNP was 1.69% per year.

In addition, BBSNP is also a perfect example of the complex causes of deforestation. BBSNP has a long border of approximately 700 km, and the park is there are villages, agriculture, and plantation forestry adjacent to the park (Kinnaird *et. al.* 2003). The high rates of interaction between the people and the forest in the area that borders BBSNP may induce humans to enter the park to clear more forest. Consequently, wildlife such as tigers (*Panthera tigris sumatrae*) and elephants (*Elephas sumatranus*) also travel outside the park borders and damage crops and livestock. In addition, conflicts over land ownership between Lampung-based local groups and the government, as well as conflicts among governmental institutions, have promoted further deforestation (Kusworo 2000; Verbist *et al.* 2004).

The dramatic loss of forest cover in BBSNP is attributed to variety of factors including illegal logging, timber concessions (denoted HPHs in Indonesia), conversion to agriculture (by opportunistic settlers and those arriving through Indonesia's official transmigration program), development of estate crops, and forest fires (Sunderlin *et al*. 2001; Suyanto *et al.* 2000; Holmes 2002). However, information about the causes of deforestation in BBSNP is lacking. Gaveau *et al.* (2007) reports that coffee prices, law enforcement, and rural poverty are the primary causes of deforestation in southwest Sumatra (including BBSNP). Suyadi & Gaveau (2007) show that in a small area (Pemerihan) within BBSNP, the cause of deforestation is il-

legal logging.

This study integrates a time series of satellite images and interview data to measure deforestation rates and to determine the root causes of deforestation in BBSNP. The detailed objectives are to provide an estimate of deforestation rates and maps of deforestation patterns and to unravel the causes of deforestation in BBSNP. This study documents the extent of deforestation in the park from 1972 to 2006 and examines the causes of deforestation using interview data. This information is crucial for future conservation because BBSNP's forest is home to some of the world's most endangered large mammals and is within the major watershed for southwestern Sumatra.

MATERIALS AND METHODS

Bukit Barisan Selatan National Park (BBSNP) is the third-largest protected area (356,800 ha) on the Indonesian island of Sumatra (Figure 1). Located in southwestern portion of the island (4° 31' to 5° 57' S and 103° 34' to 104° 43' E), it forms part of the provinces of Lampung and Bengkulu. The park extends 150 km along the Bukit Barisan mountain range and is composed of diverse topography that ranges from the coastline in the south to forested mountains in the north. Rainfall is seasonal, ranging from 3,000 mm to 4,000 mm annually, and temperatures fluctuate between 22°C and 35°C. The park is narrow in shape, with a perimeter greater than 700 km in length, and is bordered by villages, agriculture, and plantations (Kinnaird *et al.* 2003). Encroachments for agriculture and illegal logging are rife in BBSNP. Forest loss has become the greatest threat to the conservation of Bukit Barisan Selatan National Park.

This study uses LANDSAT images acquired in the years 1972, 1976, 1978, 1982, 1985, 1989, 1994, 1997, 2000, 2002, 2004, and 2006 to detect forest-cover

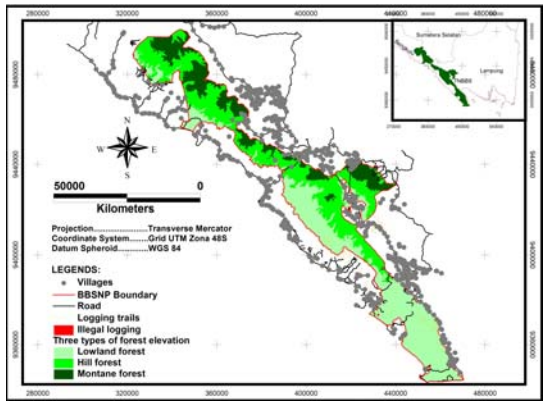


Figure. 1. Study area in southern Sumatra showing Bukit Barisan Selatan National Park (BBSNP) and forest type based on elevation.

change across Bukit Barisan Selatan National Park. All images had cloud cover of less than 2.0% and the LANDSAT images from 2006 are Scan Line Corrector (SLC) off which the gaps have been filled by Wildlife Conservation Society (WCS). The images were geo-referenced using 2006 scenes that were verified with Ground Control Points (GCPs) collected in the field by staff of WCS using Global Positioning Systems (GPS). All data were projected to the Universal Transverse Mercator (UTM) projection, Zone 48 South.

Forest and non-forest land-cover classes were classified using a supervised Maximum Likelihood Classification (MLC). I edited the classification results by manual on-screen digitization (particularly in areas where the MLC algorithm often produces misclassification errors). For land-cover change analyses, I used post-classification comparisons and time-series analyses (via transition matrixes), with forest cover at each point in time used as the base forest cover for the next point in time. This method detected the area of deforestation and any fluctuations in deforestation rates over time. Analyses were conducted via spatial analyses using a GIS software (ArcView 9.2) with geo-processing extensions. In this paper, forest refers to non-modified forest areas of old-growth vegetation dominated by closed-canopy tree cover (50%). Deforestation or forest loss is defined as complete removal of forest cover over an area equivalent to 1 ha. Non-forest comprises agricultural areas, grasslands, village enclaves, and unknown, non-forested vegetation types.

The study used a 30-m resolution ASTER Digital Elevation Model (DEM) to categories forest types by elevation. Three elevation-based categories were selected using the classification system of the Indonesian Ministry of Forestry and Kinnarid *et al.* (2003). The classes are lowland forest (0-500 m), hill forest (501-1000 m), and submontane forest (>1001 m). The ASTER DEM was assembled at the BBSNP office. The BBSNP boundary (at a scale of 1:25,000) was obtained from the BBSNP office and was corrected in the field using GPS technology by a team from the BBSNP Office, WCS, and World Wildlife Fund (WWF). Logging trails, road networks, and villages were assembled from WCS data. Locations of illegal logging were manually interpreted through on-screen digitization and were verified in the field with a GPS.

This research used data from interviews conducted in 2005-2006 in 1384 households within selected villages in and around the Park. Interviews were conducted using Indonesian and local languages (Lampungnese and Javanese). Before interviewing in each village, the WCS team and I conducted group discussions (focus groups) to identify the specific characteristics of the local society. The respondents were farmers who own cultivated land in or within 5 km of the park boundary and villagers who labored on these farms. In order to avoid reticence, (especially in areas where conflicts with park management are frequent) the interviews began with non-sensitive questions about conservation in general, progressively focused more spe-

cifically on deforestation, and finally addressed issues concerning the respondents' own farmland in Bukit Barisan Selatan National Park.

Semi-open interview techniques were used in this research with a standardized questionnaire that addressed the following: 1) personal details (including household demographics); 2) farming practices; 3) respondent origins (i.e., migrants or indigenous residents); 4) land ownership; 5) respondent expectations about increased land scarcity; and 6) respondent attitudes towards the surrounding forest. The questions included when respondents first cleared forest cover for farmland, for what reasons farmers cleared forest cover, and the area of forest that was cleared. These questions served to make the data more comparable to forest-cover data from time-series of satellite images

I assembled time-series statistics (1972 to 2006) on annual international (US dollar) and local (Indonesian Rupiah, Rp) coffee prices from the International Coffee Organization's (ICO) indicator price reports and statistics on human population from the provincial government. The local coffee price time-series data were deflated by the Consumer Price Index (CPI, 2006=100) for southern Sumatra to account for the increase in local consumer prices and agricultural input prices over time.

The study also used local and national historic records about government policies, socio-economic issues, law enforcement (including evictions of people from BBSNP), timber concessions (legal logging), and illegal logging. All of these data were collected from the BBSNP office, the Directorate General of Forest Protection and Nature Conservation (PHKA), and provincial government.

RESULTS

The Patterns of Deforestation in Bukit Barisan Selatan National Park (BBSNP)

The household interview surveys show that forest clearing in Bukit Barisan Selatan National Park (BBSNP) began in the 1960s. The image analyses justify this finding and show that before 1972, approximately 46,100 ha of forest cover in BBSNP was lost representing a 13% loss of the total area of BBSNP (356,800 ha). The image analyses also indicate that the majority (80%) of forest conversion resulted from agricultural development. The interview data indicate that the first forest clearing in BBSNP occurred in Sidorejo (Kaur, Bengkulu) in 1961, five years after transmigrants from Java came to a village (Desa Trans Kulik) near BBSNP (±2 km from the park boundary). Subsequently, deforestation began in Pemerihan (West Lampung) in 1966 and in Way Nipah (Tanggamus) and Suoh (West Lampung) in 1970.

From 1972 to 2006, deforestation in the BBSNP averaged 20 km^2 (0.64%) per year. In total, 67,225 ha of the original 310,670 ha of forest that was present in 1972 were lost, representing a 22% loss from 1972 to 2006. The trends in forest loss from 1972 to 2006 are plotted in Figure 2 and mapped in Figure 3. Figure 2 showed that two peaks in forest

loss occurred in 1978-1982 and 1997-2000. The average rate of deforestation is alarmingly high and results in declining forest cover. In contrast, the average rate of reforestation is only 1.13 km^2 per year (representing 0.94% per year).

Forest loss in BBSNP began at the buffer of the park and has progressed towards the park interior. The average rate of deforestation in the 10-km buffer is 1.83% per year, and the rate is higher inside the park. Deforestation rates in BBSNP vary with elevation. Deforestation rates in lowland forests (0-500 m), which represent 43% of the area of BBSNP, were 7.55 km^2/year. In hill forests (501-1000 m), which represent 38% of the park area, they were 9.01 km^2/year, and in montane forests (>1001 m) they were 3.43 km^2/year. Figure 4 shows that (as was the case for rates of total forest loss in BBSNP) peak forest loss in all three forest types occurred during 1978-1982 and 1997-2000. In the recent years (2004-2006), the rate of forest loss in lowland forests has decreased gradually, but forest loss in hill forests and montane forests has tended to increase. Deforestation rates also vary with slope. On relatively flat slopes (0-20°), forest loss averaged 16.5 km^2/year but the rate dropped to 0.8 km^2/year on the steepest slopes (>40°).

Based on the temporal patterns of deforestation, the study period was divided into three decades of deforestation. The highest deforestation rate in BBSNP (about 28 km^2 per year) occurred in the first decade (1972-1985). In the second decade (1986-1996), the deforestation rate decreased to 15 km^2 per year. In the most recent decade (1997-2006), the deforestation rate in the park increased and approximately 21 km^2 of forest cover were lost per year (Figure 5).

The Causes of Deforestation in Bukit Barisan Selatan National Park

The agents who play the most important physical roles in forest-cover change in BBSNP are the farmers who live in and around the park. These agents operate in separate locations and have little contact with one another; their few interactions are not sufficient to drive farmers to clear forest. Farmers them-

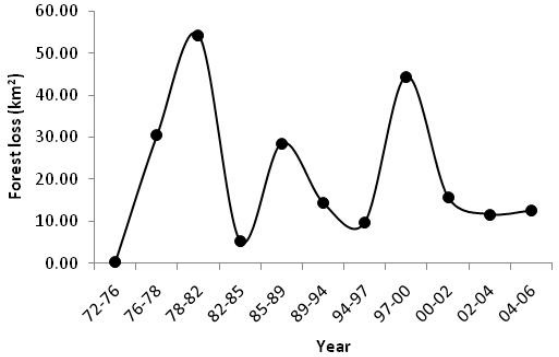


Figure 2. Forest loss in Bukit Barisan Selatan National Park, 1972-2006.

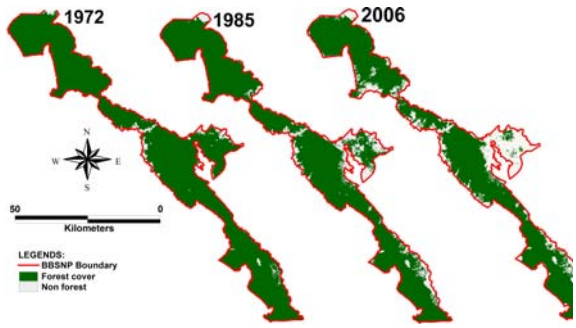


Figure 3. The spatial distribution of forest loss in Bukit Barisan Selatan National Park, 1972-2006

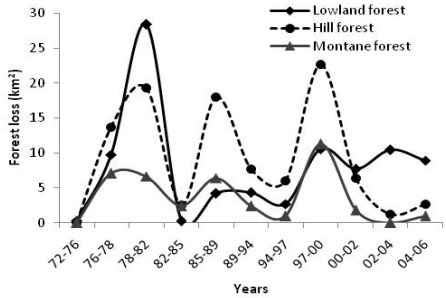


Figure 4. Forest loss in the three types of forest in Bukit Barisan Selatan National Park, 1972-2004

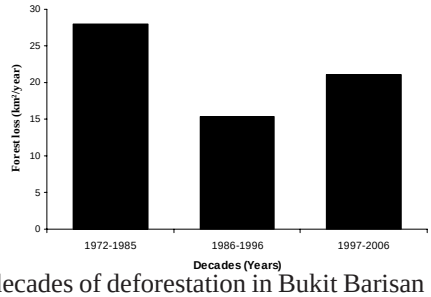


Figure 5. The three decades of deforestation in Bukit Barisan Selatan National Park

selves are not the primary cause of deforestation; instead, there are external factors that drive farmers to clear forest cover in BBSNP. The external factors are varied, and differ according to the location. The interview surveys showed that transmigration was one of the external factors that induced farmers to clear more forest in Sidorejo, BBSNP in 1961. This factor resulted in relatively more open access to the forest. The other external factors that spurred farmers were the political crisis in 1965 and the actions of timber concession companies (Perusahaan HPH) in the 1970s. Linear regression analyses indicate that logging

trails that were built by concession companies are significantly correlated with forest loss (r^2= 0.771, p = 0. 085). These external factors drove farmer to clear more forest cover in the areas of Pemerihan, Way Nipah, and Suoh. Image analyses indicate that deforestation rates caused by timber concessions in these areas were higher than deforestation rates caused by transmigration (in Sidorejo for example).

Image analyses also show that deforestation rates increased dramatically in 1978-1982 and 1997-2000 (54.28 km^2 and 44.48 km^2 per year, respectively). The regression analyses indicate that the causes of deforestation (the external factor) in these years were high coffee prices in 1978 (r^2 = 0.484, p = 0.058) and high coffee prices again in 1997 (r^2 = 0.494, p = 0.061). A linear regression model (Figure 6) indicates that local coffee prices closely predicted deforestation rates inside BBSNP (P = 0.005, r^2 = 0.47). Thus, higher local prices for coffee induced faster deforestation (b = 0.029, P = 0.028).

DISCUSSION

This research shows that deforestation in Bukit Barisan Selatan National Park has occurred since the 1960s. However, Kinnaird *et al*. (2003) report that deforestation in BBSNP began in 1985, and Gaveau *et al*. (2007) show that deforestation in BBSNP began in 1972. These are two essential sides in the ongoing debate over the rate of deforestation in BBSNP. On the one hand, Kinnaird *et al*. (2003) estimate that the deforestation rate in BBSNP from 1985 to 1999 was 2.0% per year; they predicted that in 2010 about 70% of the BBSNP would be agricultural lands or village enclaves. On the other hand, Gaveau *et al*. (2007) finds that the average rate of deforestation in BBSNP from 1972 to 2002 was 0.63% per year. The current study shows that the average rate of deforestation from 1997 to 2006 was 0.64% per year and that 69% of the area of BBSNP is currently forest and 31% is agricultural lands.

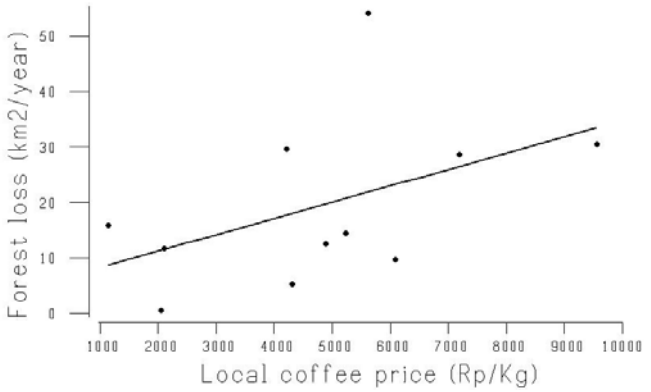


Figure 6. Results of the linear regression (solid line) between forest loss and local coffee prices.

Suyadi & Gaveau (1997) found that the external cause that drives farmers to clear forest in Pemerihan, BBSNP is illegal logging. They explain that illegal logging causes limited damage to the forest, but that this illegal activity prompted farmers to go inside the park and to clear more forest for agricultural land.

The causes of deforestation in BBSNP are complex and vary with place and time. Thus, this study does not only focus on a single set of deforestation drivers, but recognizes several forms of deforestation causes that each play a significant role in the process of forest conversion. The three levels of deforestation causes suggested by Sunderlin & Resosudarmo (1996) are agents, immediate causes, and underlying causes. In BBSNP, the agents that physically clear forest are farmers. The immediate causes of deforestation (which trigger agents to clear more forest cover) are timber concessions, illegal logging, and high coffee prices. Finally, the underlying causes of deforestation (which directly influence the behavior of the immediate causes) are lack of law enforcement and local and national socio-economic conditions. The most important causes of deforestation in BBSNP are the immediate and the underlying causes because these causes trigger more clearing of forest cover by farmers.

This study applies the three-levels explanation suggested by Sunderlin & Resosudarmo (1996) to clarify the causes of deforestation in the three decades during which deforestation occurred (Figure 5). The immediate causes of increasing deforestation in the first decade (1972-1985) were timber concessions (r^2 = 0.771) and high coffee prices (r^2 = 0.484); lack of law enforcement was an underlying cause. In areas where this sequence took place, farmers (the agents) merely filled a "vacuum" created by the loggers. In the second decade (1986-1996), deforestation in BBSNP decreased due to strong law enforcement after the third World Parks Congress (WPC) held in Bali in 1982. During this time, hundreds of families were evicted from the Pemerihan area in BBSNP (including my family and myself). In the most recent decade (1997-2006), deforestation rates in the park increased because of the high coffee prices that occurred as an effect of the Asian economic crisis of 1997-1998 and because of illegal logging that was a result of lack of law enforcement after the fall of President Suharto in 1998. Both of these factors had had a direct influence on the behavior of the illegal loggers and farmers. Figure 7 illustrates the patterns of forest loss and the causes of increase or decrease in deforestation rates.

Management Implications

This study and two previous studies (Kinnaird *et. al.* 2003) showed that deforestation is one of the greatest threats to the conservation of BBSNP. Loss of forest has proven to be one of the most difficult and complex problems facing Indonesia's conservation agencies. If we are to conserve the forests of BBSNP, we must take immediate and dramatic actions and a holistic approach. Forest management should focus on strategic efforts such as conserving the remaining

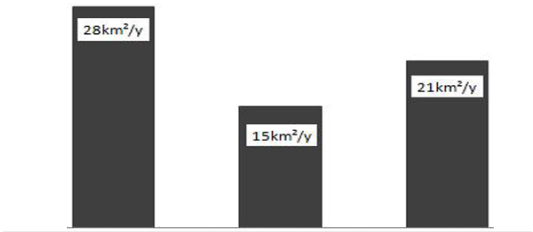
forests as well as forest restoration, law enforcement, increasing the participation of local people, increasing financial support, and increasing the incomes of farmers around the park.

Forest management must concentrate on conserving the remaining forest within the park. Managers may also need to consider restoration of lost or heavily disturbed forest and of the forest edge. The strong law enforcement present in the early 1980s in BBSNP greatly reduced deforestation especially in the southern portion of BBSNP. Therefore, law enforcement is necessary to safeguard the integrity of BBSNP from farmers who would otherwise clear the forest. Keane *et al.* (2008) suggested that law enforcement interventions are also necessary to protect endangered species. Law enforcement is also important for reducing illegal logging activities (Suyadi & Gaveau 2007).

This study found that in recent years, the deforestation rate in hill and montane forests has tended to increase. The majority of hill and montane forests located in northern BBSNP that contain "active" encroachments have experienced little regrowth. I predict that deforestation in the northern section of the park be will higher than deforestation in the southern section. Gaveau *et al.* (2007) classified the northern section of the park into a low law-enforcement zone in which accessibility for rangers is difficult and ranger patrols are lacking. On other hand, accessibility for farmers is easy (near). Therefore, the study suggests that ranger patrols should also be focused in the northern section of the park. The park manager should reactivate the patrol offices or may also consider building new patrol offices in the northern section of the park. This is important for creating better accessibility of northern section for rangers.

CONCLUSIONS

Deforestation in Bukit Barisan Selatan National Park began in the 1960s, which is earlier than previous estimations. Forest loss between 1972 and 2006 proceeded at an average rate of 20 km^2 per year or 0.64% per year. More than 22% of the forest in Bukit Barisan Selatan National Park was lost from 1972 to



1972-1985	1985-1997	1997-2006
1. Low law enforcement	1. Strong law enforcement	1. Low law enforcement
2. Timber concession/HPH (r^2 = 0.771)	2. Eviction	2. Illegal logging
3. High coffee price (r^2 = 0.484)		3. High coffee price (r^2 = 0.494)

Figure 7. The trends in and causes of increase or decrease in deforestation over three decades.

2006. This indicates that deforestation is one of the greatest threats to the conservation of BBSNP. Deforestation has occurred in lowland forests, higher-elevation hill forests and montane forests, but in recent years, deforestation in hill and montane forests has tended to increase gradually. This study predicts that the deforestation rate in the northern section of the park (which contains a large area of hill forest and montane forest) will be higher than deforestation in the southern section, which is dominated by lowland forest.

The agents that have the main physical role in forest clearing in BBSNP are farmers that live in and around the park. However, the most important of the causes of deforestation are immediate causes such as timber concessions, illegal logging, and high coffee prices; these causes induce farmers to cleared more forest. Finally, lack of law enforcement and socio-economic conditions are the important underlying causes that drive the immediate causes.

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