TROPICAL DEFORESTATION IN BUKIT BARISAN SELATAN NATIONAL PARK, SUMATRA, INDONESIA

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ABSTRACT

The Bukit Barisan Selatan National Park (BBSNP), the third-largest protected area (356.800ha) on the Indonesian island of Sumatra contains some of the largest tracts of tropical forest remaining on Sumatra. The park is home to some of the world's endangered mammals and some endemic mammals. The greatest threats to conservation of BBSNP are deforestation, but accurate estimates of the scale and rate of loss are lacking. Here, I was link time series satellite imageries, historical record, and socio-economic survey to provide an accurate estimates of deforestation in BBSNP and to unravel the causes of deforestation. The result shows BBSNP's forests have been cleared since 1960s, earlier than previous estimation. Before 1972 BBSNP forest has been lost of 46.100 ha, representing a 13% loss. From 1972 until 2006, deforestation in BBSNP averaged 0.64% per year. The forest of BBSNP 67,225 ha of the original forest of 310,670 ha that remained in 1972, representing a 21% loss from 1972 to 2006. The majority (80%) of forest conversion resulted from agricultural development. Three levels of the causes of deforestation were identified: 1) agents, 2) immediate causes, and 3) underlying causes. The agents of deforestation are farmers; the immediate causes are timber concessions, illegal loggings, and coffee price; and the underlying causes are law enforcement and socio-economic condition. The conclusions are BBSNP forests cover has been lost dramatically and in the recent years have suffered tremendous loss. The most important of the causes of deforestation are immediate causes and underlying causes because the agent never cleared more forest if there are no immediate and underlying causes.

Keywords: Deforestation, satellite imagery, socio-economic survey, Sumatra

BACKGROUND

Tropical deforestation constitutes one of the greatest threats to conservation of Bukit Barisan Selatan National Park (BBSNP) as the third-largest protected area on the Sumatra Island. UNFCCC (2007) declare that the international community faces the urgent task to reduce tropical deforestation as one of a suite of measures to reduce global warming and maintain biological diversity. One of many responses of conservation biologist 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 related deforestation with social phenomena such as what drives people to clear more tropical forest cannot be measured using satellite sensor (Turner et al. 2001). Therefore, approaches that appropriate linkages between socio-economic survey data and remote sensing datasets are important to understand trends and the causes of deforestation. Most of the studies linking remote sensing observations and socio-economic data have been undertaken at the scale of the administrative units (Wood & Skole 1998). Mertens et al. (2000) integrate remote sensing and household survey to understand the impact of macroeconomic change on deforestation in South Cameron.

Bukit Barisan Selatan National Park is good example for dramatic loss of tropical forest in Indonesia because this park contains some of the largest tracts of tropical forest remaining on Sumatra. Although BBSNP was declared as a World Heritage site by UNESCO (decision 28COM 14B.5), however in the past decade BBSNP's forest cover has declined dramatically. Much of the forest cover in BBSNP has been cleared since the early 1970s but, accurate estimates of the scale and rates of loss are lacking. Kinnaird et al. (2003) found that between 1985 and 1999 the Park lost more than 661 km^2 of forest (28%). 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 is 1.69% per year.

In addition, Bukit Barisan Selatan National Parks is also perfect example for the complex causes of deforestation. BBSNP has bordering area about 700 km, the parks is bordered by villages, agriculture, and plantation forestry (Kinnaird et al. 2003). The highly of interaction and conflict between human and wildlife and also between local people and the government in the bordering area of BBSNP may drive humans go inside park (they clear more tropical forest) and wildlife go outside borders. Kusworo (2000) and Verbist et al. (2004) noted that conflict over land ownership between Lampung-based local groups and the government and conflicts among government institutions have promoted further deforestation.

The dramatic loss of forest cover is attributed to variety of factors, including illegal logging, legal concession (legal logging), 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 causes of deforestation in Bukit Barisan Selatan National Park is lacking. Gaveau et al. (2009) reports coffee prices, law enforcement, and rural poverty is the primary causes of deforestation in southwest Sumatra included BBSNP. Suyadi & Gaveau (2007) studied in small area (Pemerihan) part of the BBSNP show that the cause of deforestation is illegal logging.

Here, I integrate time series satellite imagery, historical record, and socio-economic survey to provide an accurate estimates and maps of deforestation patterns in BBSNP and to unravel the causes of deforestation. I documented the extent of deforestation in BBSNP from 1972 to 2006 and examined what drives people to clear more tropical forest in BBSNP. Finally, BBSNP's forest is home to some of the world's most endangered large mammals and also the major watershed for southwestern Sumatra which must conserve for future.

STUDY AREA

Bukit Barisan Selatan National Park (BBSNP) is the third-largest protected area (356.800 ha) on the Indonesian island of Sumatra (Fig. 1). Located in southwestern portion of the island (4^{o} 31' to 5^{o} 57' S and 103^{o} 34' to 104^{o} 43' E), it is a 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 coastline in the south to mountainous forest in the north. Rainfall is seasonal, ranging from 3,000 mm to 4,000 mm, and temperatures fluctuate between 22^{o}C and 35^{o}C. The park is narrow in shape, with a perimeter > 700 km in length, and is bordered by villages, agriculture, and plantations (Kinnaird et al. 2003). Encroachment for agriculture and illegal logging are rife in BBSNP. Forest loss becomes the greatest threats to conservation of Bukit Barisan Selatan National Park.

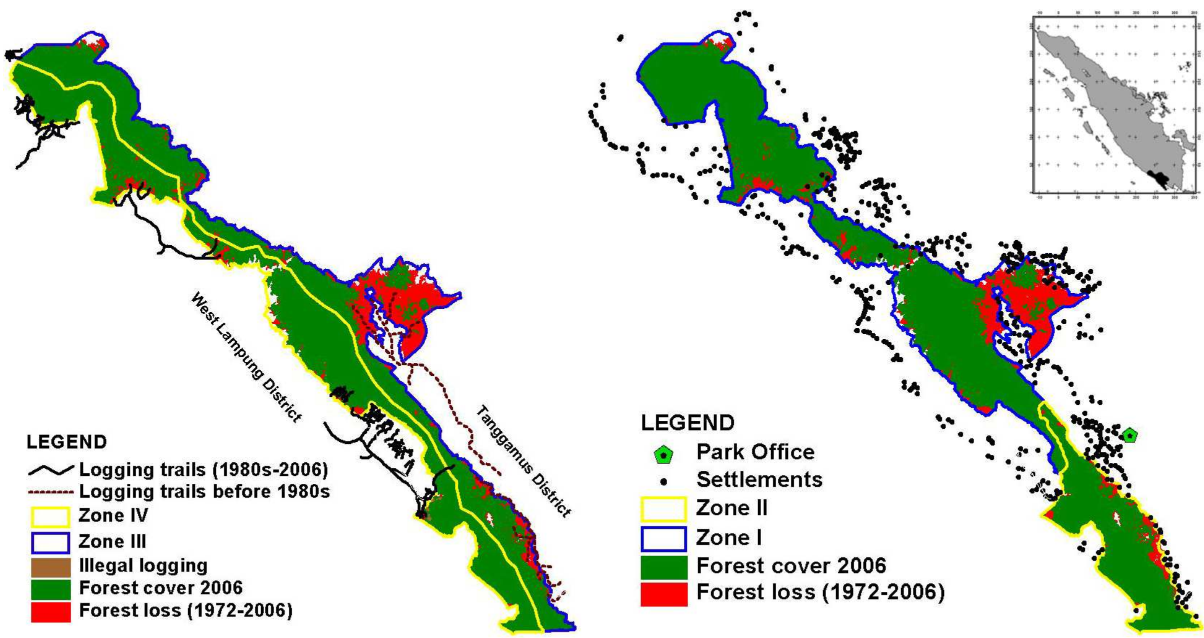


Fig. 1-The cumulative forest loss in Bukit Barisan Selatan National Park is in red. The boundaries of BBSNP's zones are in yellow and blue. The insert shows the location of the study area (black) in Sumatra, Indonesia.

METHODS

Satellite-based Estimates of Deforestation

I applied the processing method which used by Gaveau et al. (2007) for generating forest maps and assessing their accuracy. To detect forest change across Bukit Barisan Selatan National Park, I acquired Landsat MSS (1972), Landsat MSS (1978), Landsat MSS (1985), Landsat TM (1997), Landsat TM (2000), and Landsat ETM+ (2006), all image had cloud cover less than 2.0%. Landsat ETM+ (2006) scene was geo-referenced to topographic maps and also checked to the ground with Ground Control Points (GCPs) collected in the field by the Wildlife Conservation Society (WCS) using Global Positioning System (GPS). All data were projected to the Universal Transverse Mercator (UTM) projection, Zone 48 South. The other scenes were matched with 2006 scenes in x-and y through a second order polynomial co-registration technique (Schowengerdt, 1997). The spatial precision of geo-referenced was smaller than one pixel.

Forest and non-forest was identified using band 5, 4, and 3 for the TM and ETM+ data and band 4, 3, and 2 for the MSS data. Six land-cover types were distinguishable on the images: forest (□50% of closed-canopy tree cover) and non-forest comprised agricultural areas, grasslands, village enclave, and unknown, non-forested types. To generate a classification of the study area into one forest type and one non-forest type I used a Maximum Likelihood Classification (MLC) algorithm (Schowengerdit, 1997). I edited classification results manually by on-screen digitization especially in areas where the MLC algorithm often produces misclassification errors. Logging trails network was manually interpreted through on-screen digitization.

I used NASA SRTM Digital Elevation Model (DEM) to categorize forest types by elevation and slope. Elevation was categorized into four classes: lowland: 0-500m; hill: 500-100m; lower montane: 1000-1500m; and upper montane: 1500-2200m asl. BBSNP boundary was obtained from the BBSNP Office at a scale of 1:25,000, and corrected in the field with GPS, by a team from BBSNP Office, WCS, and World Wildlife Fund (WWF).

I applied the processing method which used by Kinnaird et al. (2003) to estimate deforestation rate, where rate of forest loss were calculated as the slope of the regression line between image years for a given slope/elevation class. Using these slope, I calculated time to extinction for each elevation/slope class by solving the regression equation when forest area equaled zero (0 = 1972 forest area – regression slope*years to extinction). I then subtracted 34 years to estimate years to extinction from 2006. I calculated the probability of losing forest for each elevation/slope class and created a matrix of probabilities of forest loss for combined elevations and slopes. I also assessed deforestation patterns in relation to distance from logging trails.

Defining Zones of High and Low Law Enforcement

Zones of high and low law enforcement inside the BBSNP were identified based on: (i) ecological data; socio-economic survey and interviews with BBSNP staff; and (iii) modeling spatial accessibility that modified from Gaveau et al. (2009).

<u>Ecological data</u>

Encroachments into BBSNP to be grouped into "active" or "inactive" based on whether they had been expanded the area of encroachment. Field survey revealed extensive re-growth over previously cleared forest areas in 'inactive' encroachments, but not in 'active' encroachments (Gaveau et al. 2007). Based on this turn, BBSNP to be sub-divided into two distinct zones, of no re-growth (Zone I = 245,500 ha) southern of park and of re-growth (zone II = 79,000 ha) northern of park (Fig. 1).

I assume that law enforcement has caused re-growth, while park staff focused enforcement efforts on zone II because zone I is too remote from the Park Headquarter, zone I may be assigned the zone of low law enforcement, while zone II may be assigned the zone of high law enforcement. Conversely, if remoteness rather than law enforcement has caused re-growth in zone II because farmers preferably convert forest in zone I have caused re-growth in zone I, geographic accessibility may confound the assessment of law enforcement.

<u>Interviews and socio-economic survey</u>

There is no quantitative records of past law enforcement effort in BBSNP. Four long-term staffs who had worked in BBSNP since 1980s were interviewed to determine when and where law enforcement operation had taken place in BBSNP. The interview results were cross-checked the results with independent socio-economic survey of 1000 farmers, among whom the survey attempted to locate as many evicted farmers as possible.

<u>Modeling spatial accessibility</u>

Detailed modeling spatial accessibility in BBSNP has been described previously (Gaveau et al. 2009). The model showed that zone II has remained more accessible to BBSNP staff than zone I. Mann-Whitney U tests were used to compare the mean travel times to zone I and to zone II from human settlements and from the BBSNP Headquarter office, respectively. Mean travel time values were extracted for 300 randomly selected points on zone I as having been cleared and 100 randomly selected points on zone II.

Defining Zones of High and Low Pressure

In addition, I also separate BBSNP area into two different zones, of high pressure (zone III = 178,000 ha) eastern of park and low pressure (zone IV = 178,800 ha) western of park (Fig. 1). Zone III and IV were identified based on ecological data and population density and economic growth.

Ecological data

The ecological data that used to identify zone III and IV is encroachments data in BBSNP. The ecological data showed that encroachment in zone III is higher than zone IV. There was no spatial overlap between encroachments, all of which were in the western section of BBSNP, and encroachments, all found in the eastern of BBSNP. The higher encroachment (zone III) may be assigned the zone of high pressure, while zone III may be assigned the zone of low pressure.

Population density and economic growth

One of the main underlying factors to the deforestation that I see at BBSNP is the human population increase. Lampung province grows at 2.5% every year from Javanese transmigrants. They bring with them a set of cultural and resource use practices that undoubtedly have an impact on the local ecology. Sunderlin et al. (1996) explained data on population density by district in Indonesia show a strong inverse relationship with forest cover change. There is no doubt a growing human presence in rural Indonesia has a role in deforestation. Fraser (1996) states that for every 1% increase in population, there is an approximate decrease of forest cover of 3%. Human population density around BBSNP's zone III of BBSNP in 2007 was 246 people per km^2 higher than zone IV (78 people per km^2). Human population growth around zone III between 2003 and 2007 was (5,070 people per year) also higher than zone IV (1,147 people per year). Based on this data I assume that zone III of BBSNP area has higher pressure from the human population than zone IV, for the reason that land scarcity thus they go inside the park.

I assembled time-series data of economic growth rate (PDRB) between 2003 and 2007 from Lampung Central Bureau of Statistics (BPS) for districts around zone III and zone IV. Time-series data showed that during 5 years (2003-2007) the economic growth rate in the district around zone III (Tanggamus district) is (14.32%) higher than the district around zone

IV (West Lampung district) that only 11.32%. Scientists believed that economic growth rate is the fundamental explanation for deforestation in Indonesia (Sunderlin et al, 1996). Here, I believe that zone III of BBSNP has greater pressure from the economic growth of Tanggamus district and zone IV has less pressure because the economic growth rate in West Lampung district lower than Tanggamus.

Socio-economic surveys

I and team interviewed farmers in the national languages Indonesia and local languages Javanese and *Lampungnese*. The survey questions were semi-structured with a standardized questionnaire to interview villagers and mainly open and close-ended. Before interviewing, I conducted a group discussion (focus group) in each village to understand the specific characteristic of local society. In order to avoid reticence, especially in areas where conflicts with park management are frequent, I started the interviews with non-sensitive questions about conservation in general, progressively zooming in on conservation areas, and finally on Bukit Barisan Selatan National Park.

I conducted the first survey from August to September 2006, and interviewed 200 farmers from 6 villages in and around BBSNP. The second survey was conducted in 2007, I and team interviewed 600 farmers from 11 villages inside and around BBSNP. We interviewed 48-85% of all farmers in each village. Total respondents that were interviewed are 800 farmers from 17 villages. All villages are in rural areas located inside BBSNP or on the boundary of BBSNP included enclave of park.

Coffee price time-series and historical records

I assembled time-series statistics on annual international (in US dollars) and local (in Indonesian Rupiah, Rp) robust coffee price from the International Coffee Organization (ICO) indicator price reports and from the Indonesian Bureau of Statistics. I used coffee price time-series data from 1972 to 2006. The local price time-series was deflated by the southern Sumatra Consumer Price Index (CPI, 2006=100) to account for the growth of local consumer prices and agricultural input prices over time.

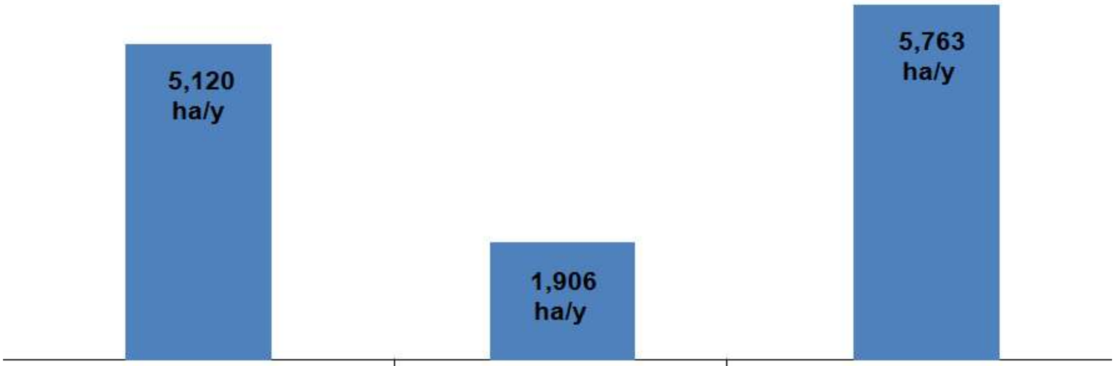
I used local and national historical records about government policies, socio-economic, law enforcement included eviction, timber concessions (legal logging), and illegal logging. Historical records collected from BBSNP office, the Directorate General of Forest Protection and Nature Conservation (PHKA), local government, and local elite's society.

RESULT

Deforestation in Bukit Barisan Selatan National Park

The result of socio-economic survey show deforestation in Bukit Barisan Selatan National Park (BBSNP) was started in 1960s. The image analysis support this finding which show that before 1972 the forest cover of BBSNP has been lost of 46.100 ha, representing a 13% loss from the area of the BBSNP (356.800 ha). From 1972 until 2006, deforestation in the BBSNP averaged 0.64% per year. The forest cover of BBSNP 67,225 ha of the original forest of 310,670 ha that remained in 1972, representing a 21% loss from 1972 to 2006 (Fig. 1). The image analysis indicates that the majority (80%) of forest conversion resulted from agricultural development and started from the buffer area of BBSNP goes inside the park. Forest covers in 10-km buffer have reduced by 113,105 ha, representing 62% loss of forest cover, at an average rate of 2.13% per year. In the last decade (1997-2006), after Asian economic crises, deforestation rate in BBSNP increase dramatically 13.00% per year, compare with the deforestation rate in the two first decades (1972-1996) are 9.09% per year.

The agents that have physical role in forest cover change is farmers, this agent operate in same or separate locations and to have little contact with one another. In the two first decades (1970s-1996), large-scale loggings (legal logging/legal concession) were a “cause” of deforestation and farmers merely fill a “vacuum” created by the loggers, in those areas where this sequence takes place. Thus, legal loggings were immediate causes of forest cover change where opened relative access to resources such as logging trails for agents. In the last decades (1997-2006), the immediate causes has become two major factor driving agricultural encroachment are illegal logging spurred faster deforestation in southern of BBSNP and high coffee price spurred faster deforestation in northern of BBSNP. The underlying causes of forest cover change in BBSNP are low law enforcement and socio-economic condition. The underlying causes are the decision parameters that have a direct influence on the behavior of the immediate causes; and the immediate causes have direct influence on the behavior of the agent to encroach BBSNP’s forest. Figure 2 shows the trend of deforestation in BBSNP and the causes of deforestation (1972-1985 and 1997-2006) and the causes of deforestation reduction (1985-1997).



1972-1985	1985-1997	1997-2006
1. Low law enforcement	1. High law enforcement	1. Low law enforcement
2. Legal logging (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)

Fig. 2-The trend and the causes of deforestation increasion and reduction

Pattern and Causes of Deforestation in Zones I and II

The forest loss rate in Zone II is lower than Zone I (□= -1130.3, $F_{1,20}$=9.07, P=0.008). Throughout the 1980s and until 1997 deforestation rates in zone II have been negligible as strong law enforcement measures were adopted by the Government to protect the biodiversity during the implementation of Indonesia's first land use plan (TGHK). Based on interview data with four long-term BBSNP staff, they claimed to have patrolled Zone II extensively, evicted all illegal farmers and removed at least 1000 farmers from BBSNP's southern peninsular. Among 1000 farmers interviewed along BBSNP boundary, 247 farmers included my family claimed to have been previously evicted, and >98% of recorded evictions occurred inside Zone II from 1982-1987. These observations support assigning Zone II as high law enforcement.

To understand the causes of deforestation in Zone I and II, I use data which I assembled from the Indonesian Bureau of Statistics (Gaveau et al, 2009) (Fig. 3). A linear regression model showed that local coffee price and the fixed factor for Zones I and II both closely predicted deforestation rates inside BBSNP ($F_{2,20}$ = 7.501, P = 0.005, r^2 = 0.471). Thus, higher local coffee prices spurred faster deforestation (□ = 0.030, $F_{1,20}$=5.811, P=0.028), a periodic effect that was especially noticeable in Zone I. Furthermore, Zone I as low law enforcement, long-term BBSNP staff claimed not have intensively patrolled Zone I, □□□□□□□□□□g 3.5 times more remote (Mann Whitney U test: Z = -14.9, P<0.001) from BBSNP Headquarter, with staff travel time of 22.45 ± 7.37 h, than Zone II, with a travel time of 6.48 ± 2.65 hr.

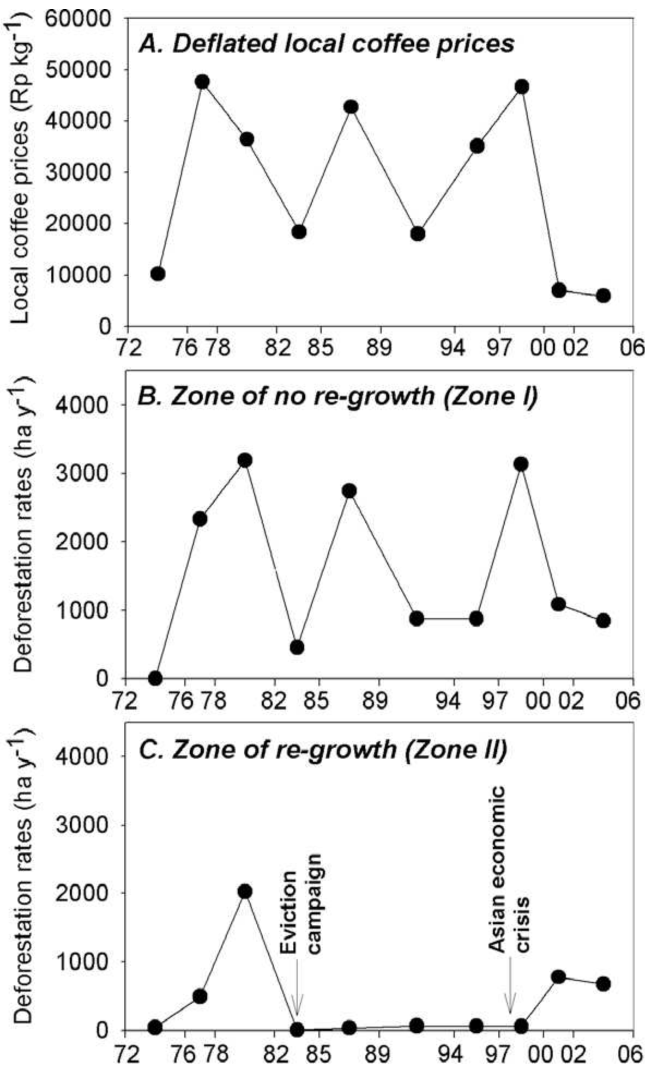


Fig. 3-Time-series showing (A) deflated (CPI, 2006 = 100) maximum annual local coffee price, (B) deforestation rates inside BBSNP's zone I, and (C) deforestation rates inside BBSNP's zone II.

Pattern and Causes of Deforestation in Zones III and IV

Image analysis indicates that there are difference pattern of deforestation between zone III and zone IV. In the zone III, the higher rates of forest loss occurred from 1972 to 1985 (2,321 ha/year), but decreased gradually in the next decades at averaged 1,209 ha per year in 1985-1997 and 1,020 ha per year in 1997-2006 (Fig. 4). On the contrary, the higher rates of forest loss in the zone IV occurred from 1997 to 2006 (1,040 ha/year). The slowest rates occurred from 1985 to 1997 (536 ha/year) and from 1972 to 1985 (110 ha/year).

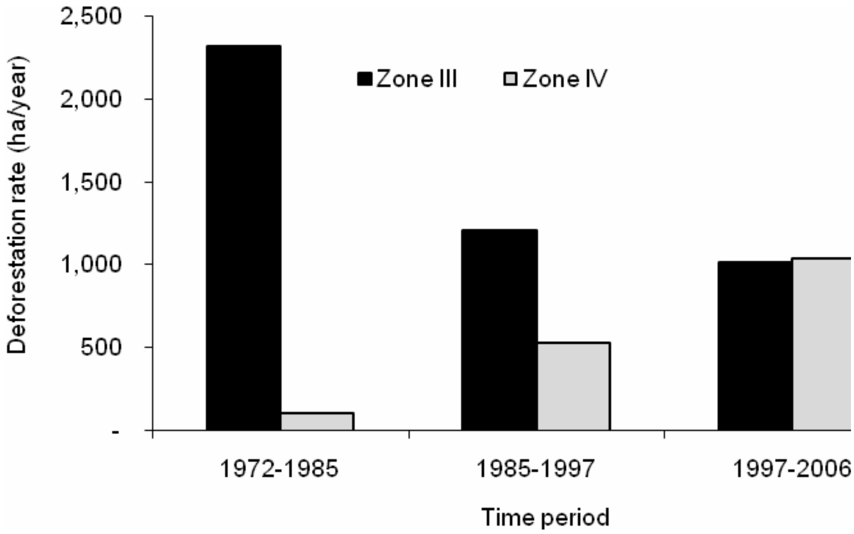


Fig. 4-Deforestation trends in BBSNP's zone III and BBSNP's Zone IV

A logistic regression model showed one of the other independent variables that had highly correlation with forest loss in Zone III between 1972 and 1985 is logging trails (P = 0.005, r^2 = 0.771). The averaged of forest cover loss which closer to logging trails (0-25 km) at average of 910 ha per year, compared with 280 ha/year on the forest that remote from logging trails (>25 km) (Fig. 1). These logging trails were developed by legal loggings since 1970s. The second independent variables that have high correlation with forest loss in Zone III between 1972 and 1985 is local coffee price (P = 0.005, r^2 = 0.484).

Deforestation reduction between 1985 and 1997 in Zone III is the effect of high law enforcement and eviction from 1982 to 1987 and deforestation reduction between 1997 and 2006 caused by topography condition, where lowland forest disappeared faster than hill/montane forest. Image analysis result showed lowland forest disappeared at the rate of 1,200 ha per year, compared with 265 ha per year in hill/montane forest. On relatively flat slopes (0-20°), forest loss averaged 850 ha/year but dropped to 50 ha/year on the steepest slopes (>40°).

Legal logging around Zone IV that started in 1970s spurred faster deforestation in Zone IV that occurred between 1972 and 1996 (P = 0.005, r^2 = 0.798). Since 1997, deforestation rates in Zone IV increased again caused by high local coffee price (P = 0.005, r^2 = 0.494) after Asian economic crises. In addition, result from socio-economic survey showed that illegal logging has become one major factor driving agricultural encroachment in Zone

IV since 1997. While illegal logging itself has caused very limited damage to the forest, this illegal activity sparked a land race among farmers inside the park.

DISCUSSION

Kinnaird et al. (2003) reports deforestation in Bukit Barisan Selatan National Park (BBSNP) has been started in 1985, in other hand Gaveau et al. (2007) showed that in 1972 deforestation in BBSNP has been started. However, this research shows that deforestation in BBSNP has been started since 1960s. Estimates of the area of annual average deforestation in BBSNP are also vary widely, ranging from a low of 0.63% per year (Gaveau et al. 2007) to a high of 2.0 % per year (Kinnaird et al. 2003). The result of this study show deforestation rate in BBSNP between 1972 and 2006 is 0.64% per year.

The information of the causes of deforestation in Bukit Barisan Selatan National Park is lacking. The detail study on small part of BBSNP conducted by Suyadi & Gaveau (2007) show that the internal factor that spurred farmers cleared forest is land scarcity, however the major factor driving agricultural encroachment is illegal logging and low law enforcement. Gaveau et al. (2009) reports law enforcement, coffee price, and rural poverty have effect to driving deforestation. This research show that the causes of deforestation in BBSNP are complex, it is possible for various kinds of causes can be spurred deforestation in the same location. It is also possible for causes can be spurred deforestation in the specific location and in certain time.

The high law enforcement in the early 1980s in BBSNP greatly reduced deforestation especially in the southern of BBSNP. This result suggest that law enforcement is necessary to safeguard the integrity of BBSNP from farmers (smallholders) who would otherwise clear forest for agricultural, Keane et al. (2008) suggesting that law enforcement interventions are also necessary to protect endangered species. In addition, this research shows that the effects of high law enforcement can persist for several years after law enforcement activities have ended, as with claims made for large mammals (Neumann, 2001). Law enforcement is also important to reduce illegal logging activities (Suyadi & Gaveau, 2007) and to control people goes inside the park for clear forest or to hunting (Wibisono, 2006).

The second way to reduce deforestation inside BBSNP and to increase farmers' income is certification of origin for sustainable robust coffee. WWF (2007) has recently urged major coffee buyers and roasters to adopt certification of origin around BBSNP. An important criterion for defining this criterion is fraught with difficulty because coffee buyers and roasters are reluctant to manage the costs of robust coffee would not discourage farmers from following growing practices within protected area. Equally, price premiums may encourage fraud within the coffee trade, given difficulties in differencing between out-park and in-park grown coffee beans (WWF, 2007).

The third effort to reduce deforestation and increase wages lies in national economic development. Better paid off-farm employment, sustained by more off-farm work opportunities in urban areas, with improved levels of rural education. Assistance for rural communities around forest especially guidance for farming practice and household economic management is important to increase their knowledge in manages their income.

This paper was opened our eyes that BBSNP forests have suffered tremendous loss in recent years. The findings have important input for the next research to explore deeper about deforestation in BBSNP. The most important tools that needed by BBSNP officer is the new accurate maps of BBSNP maps and deep understanding the root causes and the effect of deforestation to population of endangered mammals such us Sumatran tigers. To fulfill its needed we must conduct the research on the deforestation using recent satellite images link with household survey and biological survey.

CONCLUSION

Deforestation is the most important of greatest threats to conservation of Bukit Barisan Selatan National Park. Every year forest cover of Bukit Barisan Selatan National Park has been lost and in the recent decade deforestation rate increased dramatically. The causes of deforestation in Bukit Barisan Selatan National Park are complex and specific in the certain location and time. The most important of the causes of deforestation are immediate causes and underlying causes because these causes can triggers of agents to cleared more tropical forests.

RECOMMENDATION

Four recommendations to reduce deforestation in Bukit Barisan Selatan National Park:

1. Strong law enforcement to protect Bukit Barisan Selatan National Park
2. Certification of origin for sustainable robust coffee
3. Open more off-farm work opportunities for rural communities
4. Produce the new accurate maps of Bukit Barisan Selatan National Park and deep understanding of the root causes and implications of deforestation to wildlife population.

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