

Rural household participation in illegal timber felling in a protected area of West Sumatra, Indonesia

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SUMMARY

Illegal logging is a threat to tropical forests in protected areas, yet the factors motivating it need to be better understood. Here, rural household participation in timber felling in the Barisan I Nature Reserve (West Sumatra) was described, the household contextual factors relating to this participation analysed and the importance of these activities to the household income assessed. Nearly 19% of the sampled households cut or hauled timber in the Reserve, and the demand for cash encouraged participation. Alternative livelihoods such as livestock raising and agroforestry intensification outside the Reserve could reduce the need for timber felling. Knowledge about legal status of the Reserve did not affect the odds of a household engaging in timber harvesting, but greater awareness of the Reserve resulted in lower levels of income from timber. Development policy that seeks to provide livelihood alternatives to timber felling households could reduce dependence on timber and contribute to forest conservation in the Reserve. Moreover, conservation outcomes should improve if control over the protection and enforcement of the Reserve is co-managed between the government and the local communities.

Keywords: awareness, co-management, conservation, decentralization, education, income, poverty

INTRODUCTION

Timber harvesting from protected areas (PAs) is a threat to tropical forests, and an issue that has been attracting the attention of international community because it is believed to cause environmental damage and promote corruption (Brack 2005). Logging, particularly uncontrolled logging, can have variable but usually deleterious impacts on biodiversity and other globally important environmental services (Bawa & Seidler 1998; Cannon *et al.* 1998; Putz *et al.* 2001; Seneca Creek Associates & Wood Resources International 2004). It may also contribute to increased poverty and social conflict (Tacconi *et al.* 2003).

In many PAs in Indonesia, timber harvesting activities are commonplace (Curran *et al.* 2004), especially since the collapse of a strong authoritarian government at the end of the 1990s (McCarthy 2000; Forest Watch Indonesia & Global Forest Watch 2002; Hiller *et al.* 2004). The spread of illegal logging and other forest crimes into PAs occurs because valuable timber is still available in commercial volumes (Wardojo *et al.* 2001). Timber felling in PAs in Indonesia involve multiple stakeholders, including local people, logging companies, military personal and forestry officials (McCarthy 2002; Barber & Talbot 2003; Laurance 2004; Ravenel 2004; Robertson & van Schaik 2001; Hiller *et al.* 2004). Illegal logging is an opportunistic response to political change and bureaucratic confusion during transition in forest management policy as well as lack of appreciation of PA value (Environmental Investigation Agency & Telapak Indonesia 1999). Understanding the dynamics of illegal logging is an important step in finding sustainable solutions to these activities.

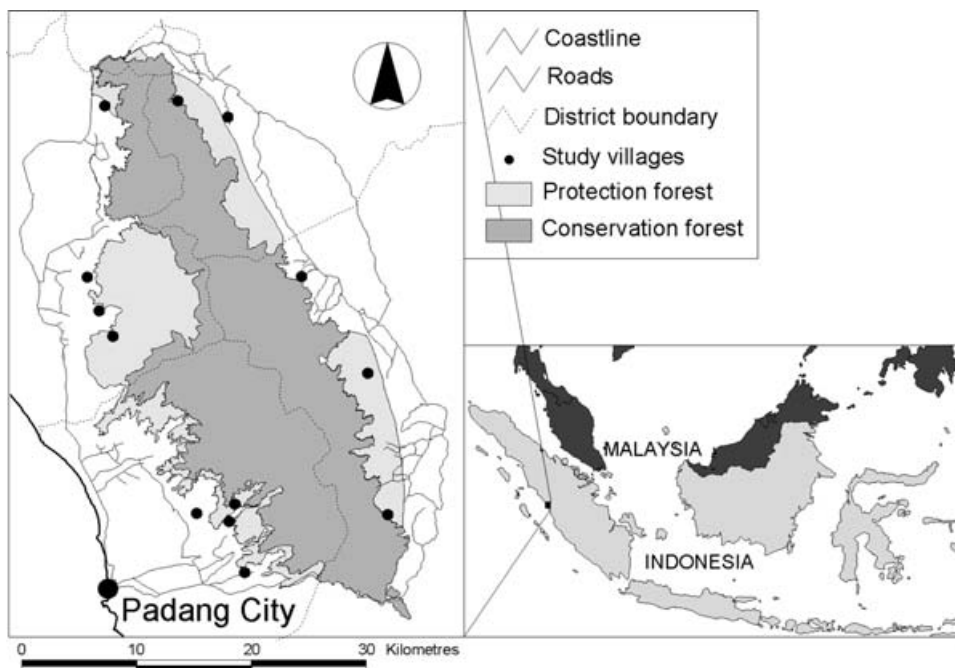
Local people involved in illegal logging are usually paid for their labour contribution and not as a function of the market value of the timber that they help extract (McCarthy 2000). Nevertheless, illegal logging provides immediate income for local communities and may aid in day-to-day survival (Schroeder-Wildberg & Carius 2003). Moreover, logging activities such as chainsaw operating or timber hauling are highly risky and are generally considered an option of 'last resort', when other livelihood opportunities are insufficient (McCarthy 2000; Sunderlin *et al.* 2005). At best, it is seen as a route to quick comparatively substantial income.

In other parts of Indonesia, participation in illegal forestry activity is a function of local livelihood context as well as the need for the cash earned by this physically demanding, risky and illegal activity. For example, a drop in income from subsistence crops led to increased illegal logging in Kutai National Park (East Kalimantan) and increased exploitation of non-timber forest products in Lore Lindu National Park (Central Sulawesi) (Angelsen & Resosudarmo 1999). The willingness of Indonesian villagers to engage in illegal logging was a function of several factors, including the need for income, whether other villagers (and non-villagers) are already illegally logging, and the recognition of loss of community control over traditional forest areas (Dudley 2004).

Barisan I Nature Reserve, located in West Sumatra Province, is an important repository of biological diversity and a source of water for rural irrigation and nearby cities; yet illegal logging takes place within its boundaries. Local people

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Figure 1 Map of Barisan I Nature Reserve in West Sumatra Province of Indonesia showing study villages.



are the proximate vectors of timber felling in the Reserve because they hold the chainsaws and haul the timber. But, what are the forces that lead households around the Reserve to engage in this activity? The considerable variety of factors presumed to underlie household decisions to participate in illegal logging, combined with a general paucity of systematic research on the subject, led to our site-specific research to improve understanding of the forces shaping local decisions about logging activities.

This research examined the practices of timber felling in the Barisan I Nature Reserve and had two objectives: (1) to describe the major timber-related activities undertaken by local households inside the Reserve and (2) to analyse the contextual factors that lead to (a) participation in timber extraction activities and (b) the relative importance of timber felling activities to the household income.

This study focused only on local (village and household) attributes and did not address externalities such as characteristics of the market that may put pressure on the households to participate. Our ongoing research has shown that not only are households the proximal agents through which all timber flows from the forest to the external markets, but also that the households as part of the *nagari* (larger village) have the capacity to cease the flow of timber from the forest (Yonariza, unpublished data 2005). Therefore the households and villages are not only the proximal participants in tree harvesting, but also are the direct agents through which illegal logging can be reduced. Households respond to the available market through buyers. Therefore, understanding the household characteristics that may lead to participation in illegal timber harvesting will greatly improve the ability to focus intervention strategies to reduce the incentive to participate in that activity, thereby contributing to long-term forest conservation on Sumatra.

METHODS

Study area

Barisan I Nature Reserve covers an area of 74 000 ha in central West Sumatra province ($100^{\circ}22'38.34''E$ – $100^{\circ}35'38.42''E$ and $00^{\circ}32'00.21''S$ – $00^{\circ}57'50.34''S$ (Fig. 1). Government Blad (GB) No. 3 on 5 January 1920 declared it a Forest Reserve during the Dutch colonial period. The Dutch government established the Reserve in consultation with the surrounding villages to ensure that the Reserve covered only unoccupied land as per the Agrarian Law of 1870 (Jepson & Whitaker 2002; Lindayanti 2003), and that all stakeholders were aware of and agreed on the boundaries. This agreement was formalized in a letter between the council of elders and government officials. Thus, citizens of villages surrounding the Reserve should be aware of its existence and extent since then.

At present, the Reserve is classified as a category VI PA, which 'should contain predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs' (IUCN [World Conservation Union] 1994). The Reserve plays a crucial role in ecosystem maintenance, particularly biodiversity conservation and water supply (UKSDA Sumbar Barat [Natural Resources Conservation Unit of West Sumatra Province] 2000).

The Reserve consists of conservation and protection zones (Fig. 1). In the conservation zone, no extractive activities can take place; in the protection zone local people can harvest non-timber forest products. Timber cutting and forest conversion is prohibited in both zones. Local people refer to the Reserve as *hutan larangan* ('prohibited forest') or *hutan lindung* ('protected forest'), phrases indicating that the Reserve

is protected from tree cutting and clearing. Villagers do not differentiate between the state-delineated conservation and protection zones in the Reserve.

The Reserve ranges in altitude from 100 m to approximately 2000 m above sea level. (UKSDA Sumbar 2000). Forest types are non-Dipterocarpaceae lowland, submontane, montane and subalpine. Some commercially valuable timber is found in all forest types, so timber cutting can occur at any altitude.

The Reserve is surrounded by densely populated villages in Solok, Padang Pariaman, Tanah Datar and Padang districts (UKSDA Sumbar 2000). Eleven sub-districts and 23 nagari are immediately adjacent to the Reserve; irrigated rice farming is the main livelihood activity in these villages, and residents directly or indirectly use Reserve products for their livelihoods.

Data collection

We purposively selected eleven nagari in four districts (Padang, Padang Pariaman, Tanah Datar, and Solok), where villagers frequently participated in forest-related activities. Subsequently, a total of 17 *orong* (sub-villages) immediately adjacent to the Reserve were purposively selected, with approximately 10% of the households in each *orong* ($n = 299$) randomly selected for survey (Pape 1993; Gallego 2005). Interview data for 60 households were destroyed in a fire, so 60 replacement interviews took place in a different *orong*, as we felt uncomfortable with re-collecting data from the same *orong*. Data collection lasted from July 2004 to May 2005.

Each selected household was visited and a face-to-face interview conducted. Primary data were collected through a questionnaire administered during household interviews. We were aware that discussing timber felling in the Reserve was a sensitive topic, so discussion of timber was initiated only during the last part of the interview when a good rapport had been developed between respondent and interviewer. The questionnaire consisted of six parts, focusing on 18 key variables related to household livelihood context and timber felling activities (Table 1).

Key informant interviews and forest observation data supplemented the household survey data and were used to describe timber-felling practices. Key informant interviews were conducted with officials from the Natural Resources Conservation Unit (UKSDA) Ministry of Forestry ($n = 4$), district level officials ($n = 6$), sub-district administrators ($n = 10$), village administrators ($n = 25$), sub-village heads ($n = 17$) and forest farmer groups ($n = 2$). Forest observations were made in forests accessed by the villages to obtain physical evidence of timber felling.

Data analysis

A household was categorized as a timber felling household (TFHH) if it had at least one family member participating in cutting and sawing timber, hauling timber from the PA, or both. Timber trading was not included in the definition of a

TFHH. If no family member engaged in felling activities, the household was categorized as a non-TFHH.

To test for the influence of household attributes on participation in timber felling activities, we used logistic regression analysis (Mahapatraa & Kant 2005) where involvement in timber felling was the binary dependent variable. We selected 16 contextual parameters as independent variables (Table 1) and performed a principal component analysis (PCA) with Kaiser normalization to reduce the number of independent variables to factors (Hair *et al.* 1998). PCA simplifies complex multidimensional variables into uncorrelated transformed factors (Cooley & Lohnes 1971). This linear transformation has been widely used in data analysis and compression (Gonzales & Woods 1992).

We performed a backward stepwise logistic regression to test which contextual variables influenced the odds that a household would participate in timber felling. The logistic regression used the principal component scores as the independent variables, and the binary variable of involvement in timber felling as the dependent variable.

We conducted two linear multiple regressions to test the relationship between household characteristics and the importance of timber felling activities to the household economy. We used the importance of timber income as the dependent variable because our respondent households did not practice bookkeeping, so it was not possible to acquire exact income quantities (Byron & Arnold 1999). However, subjective income measures have been used with success in prior research (Das & van Soest 1999; Jappelli & Pistaferri 2000). The independent variables were the 16 contextual parameters plus the additional dummy variable of involvement in timber felling. We reduced the variables following the PCA procedure above, followed by a backward stepwise multiple regression. The component scores for each household were the independent variables, and importance of timber felling as the dependent variable. For a second regression, we recalculated the PCA for the TFHH subset. This second regression evaluated which factors were related with a high importance of timber felling when households engaged in timber felling.

RESULTS

Timber felling practices

Approximately 19% of households were TFHH; these had a larger average household size, fewer out-migrants and more schoolchildren than non-TFHH (Table 2). The proportion of TFHH receiving government subsidies such as rice, health services and scholarships was higher than non-TFHH. TFHH had more months of rice insufficiency and a higher proportion of members involved in forest farming, hunting wildlife and gathering non-timber forest products (NTFPs) in the Reserve, than TFHH. Yet, both groups exhibited good knowledge of the existence of the Reserve and the illegality of timber cutting within.

Table 1 Research variables on factors affecting household participation in illegal timber felling in Barisan I Nature Reserve, West Sumatra, Indonesia. HH = household, PA = protected area.

<i>Variables</i>	<i>Type</i>	<i>Description and justification</i>
Household size	Scale	Total number of household members present during the study. Larger households may have a larger labour force and therefore a higher probability of engaging in timber felling
Number of children being schooled	Scale	Although school fees are generally low, other schooling expenses incurred may influence the need to engage in income-generating activities like timber felling or hauling
Number of out migrant members	Scale	Out-migrating family members may contribute to the total household income through outside remunerations
Number of government subsidies received	Ordinal; 0 = no subsidy received, 1 = one subsidy received, 2 = more than one subsidy received	Subsidies were rice, health service or scholarship. More subsidies indicate a lower income status and a higher likelihood to engage in timber felling
Number of high-wealth objects	Scale	Total number of cars, trucks, vans and motorbikes in the household. This is an indicator of wealth that was expected to be negatively associated with dependence on timber
Number of buffalo	Scale	Buffalo could affect involvement in timber felling, buffalo being used to haul timber from forests (possession of buffalo indicating household participation in timber felling) and/or representing an alternative income reducing dependence on timber
Involvement in forest farming	Dummy, 0 = no, 1 = yes	Establishment and use of temporary (e.g. swiddening for annual crops) or permanent (planting of perennial crops such as fruit trees) small-scale agricultural plots inside the forest. Having a plot could indicate low output in permanent agriculture, thereby increasing the probability of a household engaging in timber felling
Involvement in firewood collection	Dummy, 0 = no, 1 = yes	Collection of firewood could indicate high dependence on forest products and engagement in other forest-related activities
Involvement in hunting and trapping wildlife	Dummy, 0 = no, 1 = yes	Hunting wildlife for subsistence or market could be associated with high dependence on forest products
Involvement in gathering non-timber forest products	Dummy, 0 = no, 1 = yes	Collecting non-timber forest products for subsistence or market could be associated with high dependence on forest products
Knowledge of existence the PA	Ordinal, 0 = HH believes the Reserve does not exist, 1 = respondent is not aware of its existence, 2 = HH is aware the Reserve exists	A combination of household knowledge of the state-defined conservation and protection zones of the Reserve
Knowledge of legal status of logging in PA	Ordinal, 1 = respondent considers logging in PAs as legal, 2 = respondent does not know, 3 = respondent is aware that logging is illegal	Knowledge of laws prohibiting logging within the Reserve
Months of rice insufficiency	Scale	The months of rice production shortfall per year
Number of chainsaws	Scale	Number of chainsaws may indicate the intensity and/or frequency of timber felling activities
Presence of local forest use regulation	Dummy, 0 = no, 1 = yes	Measures whether the community has and exercises the authority to regulate forest use
Presence of local forest guard	Dummy, 0 = no, 1 = yes	Having a forest guard from the community and sponsored by the local government may decrease the participation in illegal timber felling
Involvement in timber felling	Dummy, 0 = no, 1 = yes	Categorizes whether members are involved in cutting or hauling timber
Rank of income from timber	Ordinal, range 0–5.	Perceived importance (5 being most important) of timber felling activity in household income

Since 1985, all cutting and sawing in the Reserve has been done with chainsaws, replacing hand saws. In 2004–2005, timber hauling was carried out manually (by 46 households), using water buffalo (four households), or using a tricycle

(one household). In some cases, hauling required water transportation via river or canal. Timber was hauled from the forest to a point accessible by truck. From this collecting point, sawn timber was transported to shops and end users for

Table 2 General characteristics of non-timber felling household (non-TFHH) and TFHH near Barisan I Nature Reserve, West Sumatra. Values are mean (with standard deviation) for scale variables or per cent of households for binary and ordinal variables.

Household characteristics	Non-TFHH (n = 243)	TFHH (n = 56)
Average household size	5.3 (2.2)	6.0 (2.1)
Average number of children being schooled	1.34 (1.3)	1.7 (1.2)
Average number of out-migrant members	1.0 (1.8)	0.6 (1.2)
Recipient of rice subsidy	26.3%	32.1%
Recipient of health service subsidy	15.6%	28.6%
Recipient of scholarship subsidy	23.5%	28.6%
Average months of rice insufficiency	4.8 (4.7)	6.9 (4.6)
Mean of government subsidies received	0.7 (0.9)	0.9 (0.9)
Involvement in forest farming	63.0%	71.4%
Involvement in hunting and trapping wildlife	14.4%	26.8%
Involvement in gathering non-timber forest products	14.4%	25.0%
Knowledge of PA existence		
- does not exist	16.9%	16.1%
- exists	71.2%	69.6%
- do not know	11.9%	14.3%
Knowledge of legal status of logging in PA		
- Not applicable (no knowledge of existence of PA)	15.2%	12.5%
- Legal	5.3%	3.6%
- Illegal	63.4%	60.7%
- Do not know	16.0%	23.2%
Presence of local forest use regulation	16.5%	3.6%
Presence of local forest guard	7.8%	5.4%

sale, while sawn logs were sent to a nearby sawmill. Hauling times varied from 0.5 hour to 7 hours, depending on the tree species cut, with high quality trees more distant and low timber quality trees near the forest edge.

Five TFHHs practised cutting and sawing, 37 practised hauling and 14 were involved in both activities. Hence, 19 households were involved in cutting and sawing and 51 households were involved in hauling. Among the 19 cutting and sawing households, five participated on a regular basis (four days per week, year-round), three seasonally (four days per week, between rice planting and harvesting), and 11 only when there was an order for timber. Among 51 households involved in hauling, 22 households participated regularly, eight seasonally and 21 incidentally. Of the 56 TFHH

households, 16 (29%) ranked timber first in household income (Appendix 1, see Supplementary material at http://www.ncl.ac.uk/icef/EC_Supplement.htm).

Half of the TFHHs did not own a chainsaw and household members would be hired temporarily to cut timber. In this case the patron would supply the chainsaw, pay for its operation and pay the timber cutter and hauler a labour rate based on the volume of timber. The labour rate ranged from IDR 100 000–400 000 per m³ (≈ US\$ 10–40, 1 USD = IDR 9800) depending on the tree species and distance of hauling. Because cutting and hauling 1 m³ of timber could not be finished by one person in one working day, the daily income would be about IDR 15 000–40 000 (≈ US\$ 1.5–4.0). The other half of TFHHs owned their own chainsaws and could either respond to an order, or cut trees independently and speculate on buyers. In this case, the timber cutters and haulers would be paid according to the local market price of the timber. At the time of the study, the local market price for timber was IDR 800 000–1 200 000 per m³. Respondents expressed interest in owning their own chainsaws because of the potential income from freelance tree cutting.

Factors affecting household participation in timber felling

Household attributes influenced household engagement in timber felling. PCA of 16 independent variables returned seven factors that explained 64% of the total variance (Appendix 2, see Supplementary material at http://www.ncl.ac.uk/icef/EC_Supplement.htm), namely household size and number of government subsidies received, the presence of local forest control, knowledge of the existence of the Reserve, lack of high-wealth possessions and collection of NTFPs, involvement in forest farming, the number of buffalo, and the possession of chainsaw and involvement in hunting wildlife. Household size and number of government subsidies received, lack of high-wealth possessions and involvement in gathering NTFP, and possession of chainsaws and involvement in hunting wildlife positively affected the odds of a household participating in timber felling, while presence of local forest control and the number of buffalo were negatively associated with the odds (Table 3). Knowledge of existence of the Reserve and involvement in forest farming did not affect the odds of a household participating in timber felling.

Household attributes also influenced the income rank from timber felling. Factor Component Analysis of 17 dependent

Table 3 Backward logistic regression analysis of the influence of seven PCA scores on involvement of 299 households in timber felling in Barisan I Nature Reserve (West Sumatra).

Factor	B	SE	Wald	df	p	Exp(B)
Constant	-1.802	0.194	86.474	1	0.000	0.165
Household size and number of government subsidies received	0.463	0.162	8.190	1	0.004	1.588
Presence of local forest control	-0.639	0.257	6.162	1	0.013	0.528
Absence of great wealth and collection of non-timber forest products	0.368	0.180	4.172	1	0.041	1.445
Number of buffalo	-0.308	0.170	3.266	1	0.071	0.735
Possession of chainsaw and involvement in hunting and trapping wildlife	0.635	0.145	19.049	1	0.000	1.887

Table 4 Backward stepwise multiple linear regressions using PCA scores as independent variables and rank of income as the dependent variable for 299 households surrounding Barisan I Nature Reserve (West Sumatra). NTFP = non-timber forest product.

<i>Variable</i>	<i>Unstandardized coefficients</i>		<i>Standardized coefficients</i>	<i>t</i>	<i>p</i>
	<i>B</i>	<i>SE</i>	<i>Beta</i>		
(Constant)	0.656	0.076		8.601	0.000
Household size and number of subsidies received	0.429	0.076	0.291	5.623	0.000
Involvement in NTFP extraction	-0.224	0.076	-0.152	-2.933	0.004
Involvement in timber felling and hunting	0.435	0.076	0.295	5.701	0.000
Involvement in forest farming	-0.189	0.076	-0.128	-2.479	0.014

variables, returned seven factor that explained 62% of the total variability of the original data (Appendix 3, see Supplementary material at http://www.ncl.ac.uk/icef/EC_Supplement.htm), namely household size and number of subsidies received, presence of local forest control, knowledge of the existence of the Reserve, involvement in gathering NTFPs, involvement in timber felling and hunting wildlife, involvement in forest farming and the number of buffalo. Regression analysis show that household size and number of subsidies received, and involvement in timber felling and hunting wildlife were positively and involvement in non-timber forest product extraction and in forest farming were negatively associated with timber income rank across TFHH and non-TFHH (Table 4).

Among TFHHs, only knowledge of the existence of the PA affected the income rank of timber. The PCA for 16 variables for the TFHH subsample returned seven components explaining > 72% of the variance, namely presence of local forest control and NTFP collection, household size and lack of high-wealth possessions, knowledge of the existence of the PA, involvement in firewood collection and possession of chainsaws, the number of buffalo and involvement in forest farming, low income with involvement in hunting wildlife and out-migration of family members (Appendix 4, see Supplementary material at http://www.ncl.ac.uk/icef/EC_Supplement.htm). Only knowledge of the existence of the Reserve affected the rank of income from timber felling, the association with the dependent variable being negative, indicating that the more a household was aware of the existence of Reserve, the lower was the income rank of timber (Appendix 5, see Supplementary material at http://www.ncl.ac.uk/icef/EC_Supplement.htm).

DISCUSSION

The need for cash and illegal timber harvesting

There have been few systematic attempts to understand why rural households engage in high-risk illegal timber felling and how important this activity is to their livelihoods. Realizing the importance of household contextual variables as underlying facilitators of illegal logging, the UK Department for International Development (DFID) encouraged the Department of Forestry of Indonesia to sponsor micro-level

studies to look at the role of illegal logging in local economies (Colchester 2006). This study, although not part of that programme, may contribute to fulfilling that need.

The demand for cash has prompted households to engage in timber felling, particularly in households with more members, more schoolchildren and generally low-income levels that necessitate government subsidies for health, rice and scholarships. This corroborates previous findings in Indonesia. Dudley (2004) suggested that income seeking and job seeking were the driving forces behind communities engaging in illegal logging in Indonesia. Byron and Arnold (1999) argued that timber is seen as a resource to be tapped in times of extreme need. Our research provides quantitative evidence that households, given few income-earning opportunities, may respond by undesirable or illegal natural-resource extraction activities.

The positive relationship between the number of school children and participation in illegal timber harvesting highlights an interesting conservation and development conundrum. Education may be a long-term mechanism to improve income opportunities and therefore standard of living (Psacharopoulos & Patrinos 1994; Lindenberg 2002). According to mainstream thinking, this should lower dependence on forest extraction activities. But in the communities surrounding Barisan I Nature Reserve, education is creating a short-term demand for cash to pay for children's school fees and daily expenses (such as transportation). This demand is in some cases fulfilled by earnings from illegal logging activities.

Engagement in NTFP harvesting activities in the Reserve is also a response to cash needs, however, involvement in this and other forest-related activities competes with time required for timber harvesting, explaining why the NTFP collection coefficient was positive for involvement in timber felling (Table 3), but negative in the rank income regression (Table 4). While labour is the main input in forest harvesting (Shackleton & Shackleton 2003; Tropenbos International 2005), the variable nature of NTFP collection's influence on logging via labour has not been considered.

Taken together, the results strongly suggest that the decision of a household to engage in timber harvesting activities is a response to a need for cash. Households also engage in other forest-related activities in an attempt to fulfil very basic livelihood requirements. Efforts to reduce income shortfalls could positively contribute to a reduction in illegal timber harvesting

activities. There are several factors that could generate income and reduce pressure on forests, such as increased agricultural productivity to reduce the profitability of agriculture in marginal areas, and greater off-farm employment to increase the opportunity cost of labour that might otherwise clear forests (Mulley & Unruh 2004; Sunderlin *et al.* 2005).

Livestock raising could potentially reduce dependence on forest resources in PAs (Sunderlin *et al.* 2005; Tropenbos International 2005), generating not only income, but also nutrition (Singh *et al.* 1985). However, investment in livestock could generate secondary impacts such as reduction of forest regeneration by forest grazing, fodder collection or increased NTFP harvesting. Moreover, livestock such as buffalo do not earn daily cash. Other livestock activities such as poultry raising and cow milking, both of which give daily income, could reduce the dependence on timber.

Intensification of agroforestry outside the Reserve through expanding multipurpose home gardens on marginal and perhaps even cropland could also reduce the need for timber felling. In Kerinci Seblat National Park (Sumatra), households with farms containing mixed perennial gardens were less dependent on Park resources than households with only rice farming (Murniati *et al.* 2001). Multiple products from agroforestry could provide sustained income by accessing multiple markets throughout the year. Moreover, agroforestry requires substantial labour and therefore would reduce labour available for timber felling. In addition, Indonesian multi-storey agroforestry systems often have a complex structure and high biodiversity (Diemont & Martin 2005; García-Fernández & Casado 2005), maintain forest cover (Beukema & van Noordwijk 2004) and increase habitat for wildlife (Nyhus & Tilson 2004). In several African countries, agroforestry has helped enhance and stabilize rural livelihoods, reduce pressure on PAs, enhance habitat for some wildlife species and increase the connectivity of landscape components (Ashley *et al.* 2006).

Local control

In Indonesian PAs, timber networks include local people, timber traders, forestry officials, local police, military personnel, truckers and local politicians (Schroeder-Wildberg & Carius 2003; Smith *et al.* 2003; McCarthy 2000) and a popular recommendation has been to increase law enforcement at national and international levels (Akella & Cannon 2004; Environmental Investigation Agency & Telapak 2006). International entities such as the Consultative Group on Indonesia (CGI), a group of countries lending to Indonesia, encouraged the Indonesian government to enhance law enforcement to curtail illegal logging. The World Bank supported the Forest Law Enforcement and Governance (FLEG) process, and the European Commission launched the European Action Plan on Forest Law Enforcement, Governance and Trade (FLEGT). While attempts have been made each administration since 1999 to enhance law enforcement and Indonesia appears to follow the mainstream argument of increased enforcement for

PA conservation, our study indicates that such policies are not entirely effective. When a state law enforcement officer detains a small-scale illegal timber harvester, it is difficult to sanction him according to the national policy. Article 78 point 4 of Law No. 41/1999 of the Forestry Law stipulates that the fine for illegal cutting is IDR 5 billion (> US\$ 500 000), equivalent to *c.* 390 years of wage labour, and this is therefore never applied. Law enforcement ends up freeing those arrested, after which the activities continue as usual.

Our findings support enforcement if it is locally initiated and implemented. The presence of local forest control decreased the participation of households in timber felling activities as in Leuser National Park (Aceh Province) (McCarthy 1999). Local institutions may include community forest-use regulations and the existence of community forest guards. Our findings corroborate community support for sustainable forest management (Dudley 2001, 2004) or more general sustainable resource management (Ostrom 1999; Gibson *et al.* 2005) reducing illegal logging. In West Sumatra, local communities have traditional village systems (*nagari*) that have long histories of community-based forest management, so involving local people who have traditional rights over forest access to protect the Reserve should lead to improved conservation.

An appropriate policy mechanism should be put in place for local people to participate in and have substantial management authority over PA conservation and management. Our results support comanagement of PAs (McCay & Hanna 1998; World Bank 1999), despite unresolved issues, such as how to provide clear incentive mechanisms for all actors to get involved; co-management appears to offer the greatest promise for long-term protection and enforcement of Barisan I Nature Reserve.

Awareness: important but not sufficient

Knowledge of the existence of the Reserve did not affect the probability of a household engaging in timber harvesting, but reduced the income rank in TFHHs. This increasing awareness of the PA might contribute to the reduction of logging activities, but would not be an appropriate stand-alone method to prevent illegal logging. Anti-logging messages of educational programmes cannot supersede the short-term need for cash, which can be fulfilled through timber harvesting activities that have a low risk of severe penalties from state enforcement agencies. While in general our results corroborate the IUCN recommendation to raise local community awareness and improve PA management (see Hamú *et al.* 2004), we argue that they will only achieve satisfactory results when they are part of a larger effort to improve livelihoods and localize control over forest resources.

CONCLUSIONS

Compared with Gunung Palung National Park (West Kalimantan), where 40% of the households had members who stated that logging was their primary source of cash

income (Hiller *et al.* 2004), the problem of illegal logging in Barisan I Nature Reserve appears to be less formidable. Rural households engage in illegal logging in PAs to help meet the demand for cash income, usually during the off-farm season. Households with fewer options for cash income are more likely to engage in illegal logging (Byron & Arnold 1999).

The key solution to the problem seems to be finding alternative sources of livelihood, particularly during off-farm work seasons. Many of our respondents in timber felling households claimed, 'If we had other alternative of work, we would stop timber felling.' Development policy that seeks to provide livelihood alternatives to timber felling households could reduce local dependence on timber and at the same time contribute to conservation of the Reserve. Additionally, forest conservation outcomes should improve if cooperation with local people in forest protection is developed, and if control over the resource is devolved to them.

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