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SOCIO-ECONOMIC CONTEXT OF FOREST BIODIVERSITY USE ALONG A TOWN–FOREST GRADIENT IN CAMBODIA

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ABSTRACT. — Little is known about the impact of socio-economic conditions for biodiversity conservation in Cambodia. High deforestation rates and a politically unstable recent past indicate a problematic setting for conservation efforts. Here, we studied a forest–town gradient along four villages between a population centre (i.e., Siem Reap) and the forest of the Phnom Kulen National Park in rural north-western Cambodia. We analysed whether rural communities' dependence on forest resource extraction precludes strict forest and national park protection. A total of 149 structured interviews in four local communities revealed a rapid advance of a typical forest frontier. With increasing distance to town, small businesses as income sources decreased, whereas forest-related activities and slash-and-burn agriculture increased. Local residents were strongly dependent on forest resource extraction, especially on fuel wood, and land use for slash-and-burn agriculture as cash and subsidence income sources. Most forest resources—especially large-bodied wildlife species and timber, both used predominantly by households with a better asset-based index of wealth—were rated as difficult to find. No significant relationship between the use of non-timber forest products and wealth could be identified. We conclude that the importance of forest resources increases with proximity to the forest, however, households rely on forest resources for income supplementation rather than for primary income. To prevent the continued degradation of forests, their resources and related biodiversity, greater community engagement and capacity building in sustainable forest management practices combined with stricter law enforcement, and protection from harvesters from outside of the local communities are required.

KEY WORDS. — conservation planning, distance gradient, forest resource use, shifting cultivation, Southeast Asia, wealth index

INTRODUCTION

Tropical forests play a key role in maintaining biodiversity as well as in provisioning essential ecosystem services to rural communities, but are increasingly under threat from anthropogenic climate change and deforestation (Sodhi & Brook, 2006; Sodhi et al., 2008; Corlett, 2011; Gibson et al., 2011). In Southeast Asia (SEA), deforestation rates are the highest for all tropical regions. Specifically here, research projects integrating ecological, economic, and social aspects of tropical forest conservation are crucial for advancing conservation planning (Maertens et al., 2006; Sunderlin et al., 2005, Tscharntke et al., 2007; Clough et al., 2011). Such integration is critical as clashes between development and conservation objectives are expected to increase as a result of the "rich forests, poor people syndrome", where the forest-dependent poor are excluded from accessing the wealth derived from forests (e.g., Timber; Peluso, 1992).

Although poverty in Cambodia has decreased substantially over the last 10 years, a third of the population still lives below the poverty line (UNDP, 2010) and many of its citizens continue to suffer from severe hunger (von Grebmer et al., 2009). In addition, the status of Cambodia's social and natural capital reflects a history of civil war, occupation by neighbouring states, and political instability (Chandler, 2000). Cambodia faces particularly high rates of forest exploitation and has one of the highest rates of deforestation globally (0.5% per year; cited in Ra et al., 2011).

More than 80% of the population lives in rural areas where poverty is concentrated (NIS, 2008). Forest products are likely to play a critical role in supporting rural livelihoods (Hansen & Top, 2006; Ra et al., 2011). For example, reliance on remnant forests, timber and non-timber forest products (NTFP) has been shown to be common among the 90% of the world's poor living in rural areas (World Bank, 2009; Kar & Jacobson, 2012). Such high levels of rural poverty often result in exploitative extraction practices that threaten biodiversity (Hall & Bawa, 1993; Turton, 2000; Kim et al., 2008). Especially in areas at the forest frontier, availability of forest land and open-access to forest products is high. As a result of limited capital, market access, and alternative incomes, rural villagers turn to forest clearance for agriculture and forest resource extraction. Restricting or prohibiting forest resource utilisation on biodiversity conservation grounds is ethically problematic, however, with local communities relying on these resources for survival (McDonald et al., 2007). Sustainable forest management (UNCED, 1992) as exemplified by community forestry initiatives or the growing market for sustainably harvested forest products, may present an opportunity to balance conservation and development goals (e.g., Sunderlin et al., 2005; McDonald et al., 2007; Yemiru et al., 2010). Unfortunately, detailed case studies integrating development and conservation initiatives are still limited in Cambodia (but see Lo Cascio & Beilin, 2010). In fact, further research and data are even needed on fundamental aspects of the human–forest relations in Cambodia to improve the effectiveness of natural resource management (Ra et al., 2011).

To address these issues, we investigated a town-to-forest gradient along four villages to determine socio-economic influences on biodiversity conservation in the Phnom Kulen National Park (PKNP) area, Cambodia. Closest to the forest (see Fig. 1), we expected (i) the most recent local immigration, (ii) an increasing availability and utilisation of forest resources as well as more land under shifting cultivation (chamkars), and (iii) a shift of income generation from labour (off-farm employment) or permanent agriculture to income generated from shifting cultivation and forest products. The pervasive poverty in the project region further suggests that (iv) forest resource utilisation is an important livelihood strategy (Vedeld et al., 2007). If so, integrated conservation and rural development prescriptions may need to be more seriously considered for the area. We address these research hypotheses by using face-to-face household

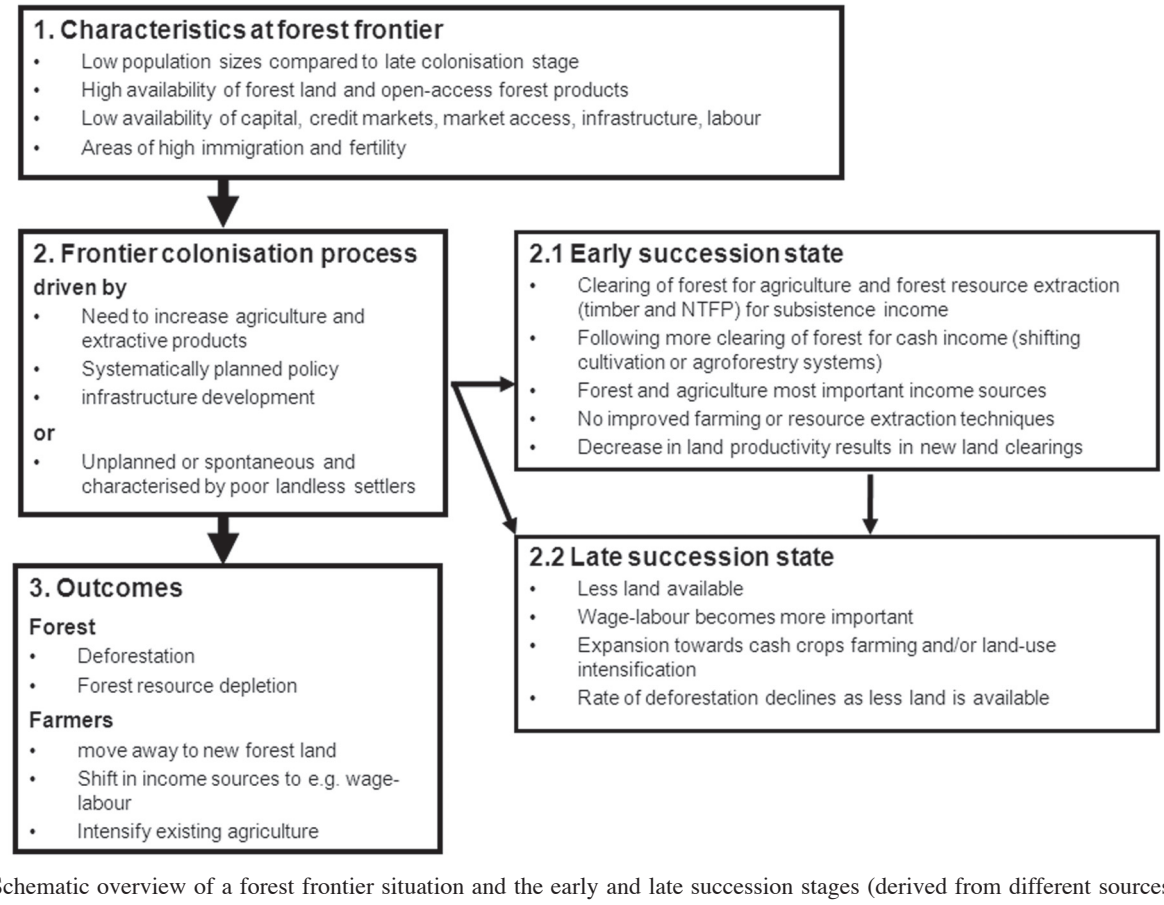

Fig. 1. Schematic overview of a forest frontier situation and the early and late succession stages (derived from different sources; Pichon, 1996; Barbier, 1997; Marquette, 2006; Rola & Coxhead, 2005; Sills & Caviglia-Harris, 2009)

interviews on immigration history and major sources of income. We then analyse the importance of forest resources for cash and subsistence income generation, and assess land use patterns. Finally, we consider the significance of forest resources to the wealth of local communities (as measured by a relative wealth index) and problems related to forest resource utilisation. Ultimately, this research is intended to inform future conservation management initiatives by creating awareness for the sustainable use of biodiversity and forest resources by local communities.

METHODS

Study area. — The study area is located in the Angkor basin in north-western Cambodia near and inside the PKNP (IUCN & UNEP, 2009; Fig. 2), 45 km northwest of the regional population centre of Siem Reap. The Angkor basin experienced high deforestation (23% in the years 1989–2005) mostly around the PKNP area (Gaughan et al., 2009). The park is an IUCN II protected area covering 37,500 ha of highly degraded vegetation; primary forest and secondary forests border shrubland and shifting cultivation (Department of Forestry, unpublished 2004). In the west, two logging enterprises hold extensive concessions, but illegal logging activities are also reported from within the park (Hinrichs & McKenzie, 2004). Until 1998, Khmer Rouge rebels used the forests as a hiding area. Thorough biodiversity assessments are very dangerous due to remnant landmines (Hou et al., 2004).

We selected four settlements close to and within PKNP along a street (dirt road) connecting the regional population centre Siem Reap to the Thai border (Fig. 2). Komprom (KP-1; the largest community) is situated ~40 km from Siem Reap, and 5 km from the local market at Banteay Srey. Next are Kundriem (KR-2) and Kna Rung Veas (KRV-3), the latter partly located inside the national park with a regional tourist attraction (Kbal Spean). The last settlement Tout Kru (TK-4) is located directly beyond the national park.

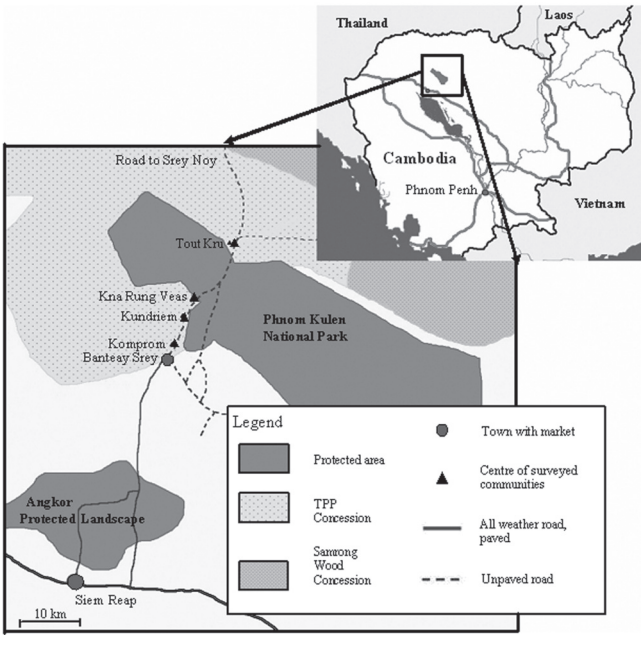

Fig. 2. Overview map of Cambodia with detailed map of the study site. The map illustrates the distance-to-town gradient with the location of the surveyed villages (i.e., Komprom [KP-1], Kundriem [KR-2], Kna Rung Veas [KRV-3], and Tout Kru [TK-4]) along the road from Siem Reap to Phnom Kulen national Park (PKNP). It also shows the localities of surrounding concession companies.

Collection of survey data. — A pilot study (n = 4) to test and optimise the main questionnaire was conducted and subsequently questions refined for a better mutual understanding. We used a cross sectional survey to collect data from 149 households (18.7% of the total number of households) between Aug–Dec.2006. We randomly selected a house in one of the four study villages in the field. We determined the Global Positioning System (GPS) position of all households and calculated the direct distance (in km) to Siem Reap. We interviewed one adult member of each selected household face-to-face (50% women, 50% men). A trained assistant conducted the interviews in the local language (Khmer). Answers were immediately translated into English and recorded.

Survey design and variable definition. — The questionnaire was divided into six parts: household characteristics, land holdings, occupational variables, resource use patterns, and the problems concerning forest resource use, wildlife use and availability, and awareness of environmental issues (Supplementary material, Appendix 1). As forest resource use and hunting are sensitive topics, they were addressed only during the second half of the interview when a good rapport between respondent and interviewer had been established. We provide species names if this particular species was present and common in the study area or the species widely known (e.g., tiger).

We grouped income sources into five categories: (i) permanent agriculture, (ii) forest-related activities, (iii) shifting cultivation, (iv) small business (e.g., shop or restaurant), and (v) wage labour. Wage labour included, e.g., working in a brick factory, cutting trees for others, or employment by the public service. Shifting cultivation (in the local language "chamkar") refers to agricultural land recently cut from the forest and left to fallow after 3–4 years.

We acquired information whether the respondent and his/her family was born in the four villages ("native") or how many years ago the respondent immigrated ("immigrant"). We refer to people who have lived in the area for more than 30 years also as "native".

Our measure for household wealth, the wealth index (WI), is based on assets, which are often highly correlated with household wealth (Zeller et al., 2006). Moreover, assets are much less affected by seasonality and recall bias (i.e., certain information is more difficult to recall than other after some time) than actual measures of income (McKenzie, 2004). The index was constructed by principal component analysis (PCA) from four sub-variables (ownership of vehicles; ownership of a fuel efficient stove; frequency of wildlife consumption;

Table 1. Characteristics of the surveyed communities; standard deviations (SD) are given in brackets.

	Komprom (KP-1)	Kundriem (KR-2)	Kna Rung Veas (KRV-3)	Tout Kru (TK-4)	Total
Percentage of households interviewed /%	11.9	29.9	26	26	18.6
Mean household size	5.8 (± 2.0)	6.4 (± 2.1)	5.8 (± 2.5)	5.3 (± 2.3)	5.9 (± 2.2)
Mean number of children under 15 years	2.9 (± 1.8)	2.7 (± 1.8)	2.7 (± 1.9)	2.0 (± 1.8)	2.7 (± 1.8)
Percentage of immigrants /%	35.2	62.5	20	75	44.3
Mean years since immigration	5.7 (± 3.2)	6.3 (± 4.2)	6.4 (± 3.6)	4.6 (± 2.3)	5.8 (± 3.5)
Ownership of permanent rice fields /%	16.7	32.5	68.6	15	32.9
Rice field size /ha	1.0 (± 0.4)	1.6 (± 0.8)	2.3 (±2.4)	2.8 (± 2.3)	1.9 (± 1.9)
Ownership of chamkar /%	35.2	50	74.3	65	52.3
Size of chamkar plot currently used /ha	0.9 (± 0.4)	1.5 (± 1.3)	1.9 (± 1.3)	2.4 (± 1.5)	1.7 (± 1.4)
Total land size per household /ha	1.4 (± 1.3)	2.4 (± 1.9)	4.5 (± 4.0)	2.9 (± 2.9)	2.8 (± 3.0)

and number of bicycles owned divided by the number of household members). Informed by the method presented in Zeller et al. (2006) and by personal experience, asset variables were chosen to reflect a locally applicable measure of relative wealth. The first principal component variable is interpreted as the WI value for each household (for details see Zeller et al., 2006). For more detailed variable description see Appendix 2.

Statistical analysis. — A multinomial logit model was used to assess the effect of contextual factors ("distance to forest" [distance], WI, and "years living in the area" [years]) on household income sources. Income source was treated as a non-ordinal, multinomial outcome with five income categories (see above). The best model for predicting household income source was identified using the Akaike Information Criterion (AIC) based model selection.

We used one-way ANOVAs (significance level $\alpha = 0.05$) to test for differences in the dependent variable "distance to town" and the response variables "collection of forest resources", "extracting timber for subsistence", "extracting fuel wood for subsistence", "perceived availability of forest resources", "wildlife consumption", "traditional medicine use", and "chamkar size". In addition, we used one-way ANOVAs to test for differences between the dependent variable "immigrants or natives" and the response variables "chamkar size" and "rice field size". Further, we used ANOVAs, to test the differences between the WI (sqrt(1/X) transformed) and different sources of income. A Spearman rank correlation was used to test for correlations between the perceived availability of wildlife and the WI. All statistical analyses were performed in R (v.2.12., R Development Core Team, 2011) and SPSS 14.0 (SPSS, 2005).

RESULTS

General information on households. — Mean household size was similar among the four communities (see Table 1). The mean number of children under 15 years was 2.7 ± 1.8 (SD). About 45% of respondents had moved into their community less than 15 years, on average, six years ago. In KR-2 and TK-4, the number of immigrants exceeded the number of native households. Most of the immigrants (80%) stated that they moved because of better access to forest resources including chamkars. (Table 1; for basic settlement data, see Supplementary material, Table S1). Remarkably, 92% of these immigrants owned a chamkar.

Major cash income sources. — Agriculture (permanent rice, other crops, and livestock) accounted for 26.2% of all cash income sources mentioned, forest-related activities for 27.0%, chamkar 17.4%, and the off-farm activities such as wage labour and small business for 15.9% and 13.0%, respectively.

The choice of income sources was best predicted by a model including the variables "distance to forest" and "years living in the area" (Table 2). WI was not a good predictor variable (Table 2). Fig. 3 shows the predicted probabilities of the choice of income sources by households in relation to distance to forest living for 5, 15, and 30 years in the study area. The income source "forest related activities" and "chamkar" were always higher near the forest. In contrast "labour" was always higher farthest away from the forest. Small business as income source is more often practiced farther away from forest. Respondents that recently moved to the area (5 years ago) have more often "small business" as source of income, and "Agriculture" as income source increases for people living longer in the area (30 years).

Importance of forest resources as source of cash and subsistence income. — The extraction of forest resources (collecting fuel wood, cutting trees for charcoal and timber) was mentioned by 40.9% of all respondents as a source of cash income. Whilst only 10.1% of all households relied exclusively on forest resources (mainly NTFP) as the only cash income source, 30.8% used forest products as a complimentary cash income source.

Table 2. Results for the multinomial logit model selection for predicting household income source identified using the Akaike Information Criterion (AIC). LL = maximised log-likelihood; K = the number of estimated parameters; AICc = adjusted Akaike information criterion; ΔAICc = difference between AICc and the lowest AICc value; w^i = AICc weights

Predictor variable	LL	K	AICc	ΔAICc	w^i
distance+years	–204.5	12	433.4	0.0	0.8
distance+years+WI	–202.5	16	437.8	4.4	0.1
distance*years	–203.4	16	439.6	6.2	0.0
years	–212.4	8	441.0	7.5	0.0
distance*WI+years	–200.9	20	443.0	9.6	0.0
WI*years+distance	–201.3	20	443.7	10.3	0.0
distance*WI*years	–196.6	32	460.2	26.7	0.0
NULL	–232.2	4	472.4	38.9	0.0
WI	–229.3	8	474.7	41.3	0.0

In addition, forest resource collection was mentioned as an important source of subsistence income for family consumption by 55.3% of all respondents. The most frequently collected forest products were fuel wood (71.1%) timber (17.4%), bamboo (15.4%), wood for charcoal production (10.1%), and wildlife (9.4%). The distance to town was similar for respondents collecting and not collecting forest resources (ANOVA, F = 1.543, d.f. = 1, p = 0.216).

Only 3.4% of all people actively cut timber as a major source of cash income; five respondents stopped selling timber because of low availability (Table 3). Households extracting timber for sale were located significantly farther away from town and households extracting timber only for subsistence were located significantly closer to town (ANOVA, Tukey post-hoc analysis, F = 4.809, d.f. = 2, p = 0.024). Fuel wood was collected by 97.3% of respondents.

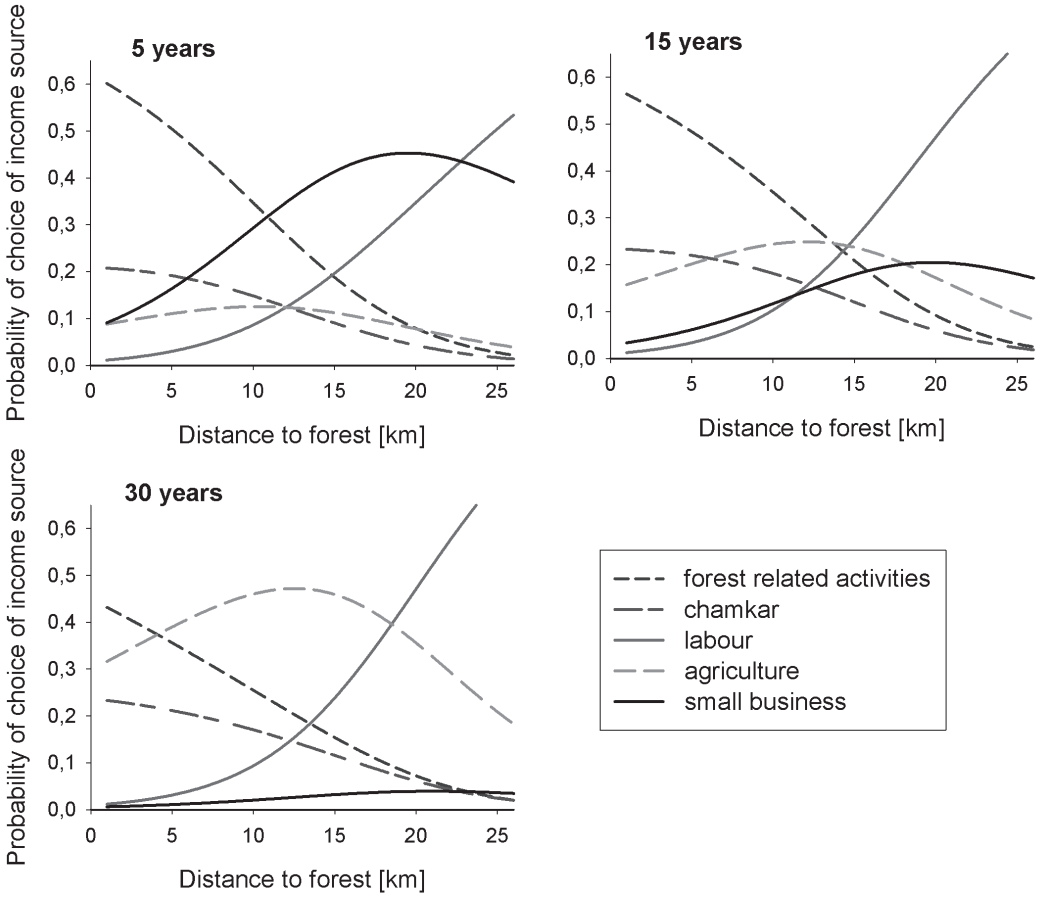

Fig. 3. Predicted probabilities of the choice of income sources by households in relation to distance to forest living for 5, 15, and 30 years in the study area.

Table 3. Use of most often extracted forest resources; % = percentage of all respondents; *N* = number of respondents.

Forest resource		Utilisation of forest resources			
		Sale	Family use	Stop selling	Total
Timber	N	5	8	5	18
	%	3.4	5.4	3.4	12.1
Charcoal	N	15	0	1	16
	%	10.1	0	0.7	10.7
Fuel wood	N	54	50	2	106
	%	36.2	33.6	1.3	71.1
Rattan / Bamboo	N	8	3	5	16
	%	5.4	2.0	3.4	10.7

Of these, 34% sold fuel wood as a source of cash income and were, on average, located farther away from Siem Reap. On average, households collecting fuel wood for subsistence were located closer to town (ANOVA, Tukey post-hoc analysis, F = 3.978, d.f. = 2, p = 0.022). Charcoal was sold by 15 households (10.1%) but it was not used as a source of energy by respondents themselves. Few households collected rattan (6%) or bamboo (9.4%) although the availability of these products was rated high (Fig. 4). Respondents stated that the profit from rattan and bamboo was insufficient. Only two households owned resin trees; one household collected resin for income generation.

Respondents perceived a declining availability of forest resources, especially, of timber and fuel wood, but also for wildlife and resin trees (Fig. 4). Four fruit tree species (*Nehalem litchi*, *Litchi chinensis*, *Langsium domesticum*, and *Willughbia* spp.) and one plant species (*Goniothalamus repevensis)* used for cosmetics were named in particular. Over-harvesting and illegal cutting trees were stated as reasons for decline. The decline of forest resources was perceived as significantly less severe in the most remote village TK-4 farthest away from town (ANOVA, Tukey post-hoc analysis, F = 33.087, d.f. = 3, p < 0.001).

Conflicts of the local communities with wildlife hunting and use. — Of all respondents, only one reported hunting as a major source of cash income and one admitted to hunt and sell animals but added that this was not sufficient as a source of regular income. Traders were observed by villagers to sell wildlife harvested elsewhere in the study area. Of all surveyed households, 7.4% hunted wildlife for subsistence food, and 2% for traditional medicine. Many respondents (68.5%) claimed to consume wildlife; 45% of these state to do so "almost never". The most commonly consumed wildlife species were reported to be deer (36.4%), wild pig (*Sus scrofa*, 36.0%), Burmese hare (*Lepus peguensis*, 5.8%), and monitor lizard (*Varanus* sp., 5.8%; see Supplementary material, Table S2). Of the respondents consuming wildlife, 98% stated that they eat wild animals because it tastes better than domestic meat. The majority of all respondents (86.8%) agreed that prices for wild meat were higher than for domestic meat.

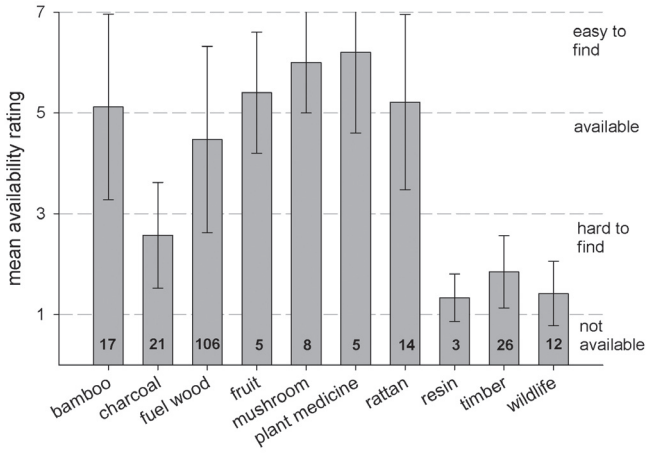

Fig. 4. Perception of changes in the availability of forest products. The availability of the different species was rated from 1 (very hard to find) to 7 (very easy to find). Error bars represent SD. Numbers in bars represent sample size (n).

Traditional medicine made from wildlife was used by 20% of the households, with Asian slow loris (*Nycticebus bengalensis)*, Malayan porcupine (*Hystrix brachyuran)*, Sunda pangolins (*Manis javanica)*, Chinese serow (*Capricornis milneedwardsi)*, Burmese hare, and different species of snakes used most often. Wildlife medicine was believed by respondents not only to be cheaper than western medicine, but also to be more effective.

Results from rating wildlife species abundances indicated that all species were perceived to be less abundant compared to five years prior to the survey (Supplementary material Fig. S1). In particular, wild pig was reported to be the most abundant while pangolin, sun bear (*Ursus malayanus*), and Asian slow loris were reported as being the least abundant species.

When assessed by increasing distance from town, the number of households consuming wildlife was not found to be significantly different (ANOVA, F = 0.807, d.f. = 5, p = 0.546). However, the number of households reporting use of traditional wildlife medicines was found to be significantly greater with increased distance from the population centre (ANOVA, F = 3.425, d.f. = 1, p = 0.066).

Land use patterns with focus on chamkars. — Permanent rain-fed lowland rice cultivation (hereafter permanent rice fields) was highest in KRV-3, while rice cultivation was only practised by a small number of households in TK-4 and KP-1.

Table 4. Test of differences (*ANOVA*) between households with and without a certain income source with respect to the mean Wealth Index (WI). Significant predictors ($P < 0.05$) in **bold**; "+" or "–" indicates whether households with a specific income have a higher or lower mean WI; results are from 10 single ANOVAs.

Main income sources	F	P-value	Wealth index
Small business	7.288	**0.008**	+
Labour	4.315	**0.040**	–
Agriculture	6.202	**0.014**	+
Forest-related activities	0.623	0.431	
Forest resources as income source			
Timber	7.364	**0.007**	+
Wildlife	23.267	**<0.001**	+
Fuel wood	8.714	**0.004**	–
Charcoal	2.306	0.131	
Rattan and bamboo	0.923	0.338	
Chamkar	0.528	0.469	

Other cash crops were not frequently cultivated. Only eight households (5.4%) reported owning permanent agricultural land. Only in KRV-3 and KR-2, households reported the possession of unused forest land (7.5% and 17.1%).

About half of the cultivated chamkar land reported by respondents was used primarily for banana, rain-fed upland rice, and papaya cultivation in decreasing order of frequency. Chamkars, which are on average farmed for 3.7 years (± 2.3 SD) and then fallowed, are important cash income sources for 38.3% of all respondents. The area of chamkar land reported was highest in villages closer to the forest (ANOVA, Tukey post-hoc analysis, $F = 4.394$, d.f. = 3, $p = 0.007$). We found no significant difference in mean chamkar size between natives and immigrants (ANOVA, $F = 1.1894$, d.f. = 1, $p = 0.17$). However, on average immigrants reported owning significantly smaller rice fields (ANOVA, $F = 8.911$, d.f. = 1, $p = 0.003$).

Influences on wealth index (WI). — The first principal component variable used as the WI variable had an Eigen value > 1, and explained 30% of the total variance. Households reporting small business or agricultural activities had a significantly higher mean WI than households that did not report conducting these activities (Table 4). In contrast, respondents indicating labour as a livelihood strategy had a significantly lower mean WI than those not having to rely on wage labour. The use of timber and wildlife as sources of income were associated with a higher and fuel wood with a lower WI, respectively (Table 4). We found no significant effect of WI on chamkar, rattan, or charcoal as source of income (Table 4).

The perceived availability of wildlife was positively correlated with the WI (Spearman, correlation coefficient = 0.312, $P < 0.001$). Moreover, mean WI was higher for households reporting use of traditional wildlife medicines than for households that did not (ANOVA, $F = 6.627$, d.f. = 1, $p = 0.011$).

Problems related to forest resource collection for village residents. — A large proportion of respondents (81%) stated that they are strongly affected by declining forest resources. More than 90% of respondents stated that people from outside the village (respondents claimed to not know outsiders' identities) extract forest products—mainly timber (69.8%) and fuel wood (57%). Of all respondents, 41.8% stated that individuals with sufficient resources to pay "fines", purchase equipment for forest resource extraction. Also, those who benefited from personal relations to government and/or law enforcement officials were claimed to have superior access to forests. Roughly 60% of respondents stated to be aware of environmental problems caused by deforestation. The problems mentioned were mostly related to climate change, such as droughts and increased hot days, storms and flooding events. Respondents also had concerns about resource loss for future generations.

DISCUSSION

We investigated the current pattern of forest resources use in relation to local livelihood strategies and wealth in rural Cambodia. Along a town-forest gradient, we found a forest frontier situation with high immigration, availability of forest resources, shifting cultivation intensity, and a shift in income sources reported by households located closer to the forest. We did not find forest resource use (especially NTFP use) to significantly contribute to household wealth.

Forest frontier situation. — In developing countries, forest frontiers are characterised by typical settlement processes illustrated by Fig. 1. As expected, colonisation proceeded along the main road from Siem Reap, reaching and trespassing PKNP. This is also shown on publicly available regional Landsat Imagery between 1990 and 2000 (NASA, 2005). We found recent immigration into the region for forest resources, in particular to establish chamkars, to be substantial. Forest land for chamkar use appears to be a "free" open access resource as indicated by the lack of difference in the size of

chamkars between recent immigrants and native residents. As a consequence, the entire study area is now predominantly characterised by small permanent rice paddies cultivated at low intensity, and chamkars. The PKNP is less affected, but encroachment inside the park has been reported (Hinrichs & McKenzie, 2004). Immigration into frontier areas is also a pattern of concern in other parts of Cambodia (NGO Forum Cambodia Project, 2003). Similar findings from SEA come from the Philippines and Indonesia, where migration into rural areas is driven by availability of "free" forest land (Amacher et al., 1998; Barkmann et al., 2010).

In line with the forest frontier hypothesis, forest-related activities are systematically distributed along the forest-town gradient. In the two communities closest to the national park, forest resources (timber, NTFP) and chamkars are intensively used and dominate household income sources. Closer to Siem Reap, chamkar size is notably smaller, likely due to lower land availability and opportunities for wage labour. Most households there do not have the equipment or transportation to extract resources from the protected forest 5–10 km away. As an alternative, many villagers now work as field labourers for others who own equipment, or have shifted to other labour work (e.g., brick factory). In sum, our data suggests that the study area is, in fact, experiencing the rapid advance of a typical forest frontier.

Chamkar as income source. — We found that chamkars potentially offer a good source of income presuming land is still available (Rasul & Thapa, 2003). However, shifting cultivation poses a threat to forests if practiced unsustainably or if old growth forests are cleared (e.g., Colm, 1997). In addition to high endogenous population pressure, immigration rates are high and, hence, add pressure on forests by claiming land for chamkars. At a forest frontier with potential cropland, eventual conversion from shifting cultivation to permanent cropland is likely (Barbier, 2004). Thus, we would expect a creeping deforestation process until nearly all accessible land is converted into cropland as it has often been observed in Cambodia and SEA (Hou et al., 2004; Sodhi & Brook, 2006). Interestingly, cash crops are only cultivated by a small proportion of farmers in our study area, generally observed as a household strategy in later frontier successions (Maertens et al., 2006) possibly due to poor soil quality or lacking knowledge on cash crop management.

Forest resources as income source and to accumulate wealth. — We identified the collection of timber and NTFPs to be the most important cash and subsistence income sources in our study area. Moreover, respondents claim that the decreasing availability of forest resources impacts them negatively. This indicates that villagers are highly dependent upon local forest remnants; results which are consistent with reports from other areas in Cambodia (World Bank, 2006) and in SEA, where large segments of the population rely on forest resources (Vedeld et al., 2007; Kar & Jacobson, 2012).

For conservation planning it is important to understand the role of forest resources in income generation and poverty alleviation (Paumgarten & Shackleton, 2011; Ferraro et al., 2011). In our study, only 10% of the interviewed households were found to rely on forest resources as their primary source of income. As we found no correlation between forest resource utilisation as an income source and the indicator of poverty (i.e., the WI) at large, the use of forest resource does not seem to increase wealth. However, 40% of households use forest resources as a source of income, and almost one third (30%) indicated that they rely on forest-based activities as a supplementary source of income. It is very likely that these households are highly susceptible to a further reduction in the availability of forest resources because alternative income sources such as small business may not be readily available. This is common in tropical developing countries; however, this link can be diverse and differs depending on the country or specific circumstances (e.g., Wunder, 2001; Angelsen & Wunder, 2003; Adams et al., 2004;). Due to the distinct differences in economic importance of forest resources found in our study, we discuss the most important forest resources below.

Valuable but rare and illegal to harvest: Timber and wildlife. — Timber and wildlife were the only forest-based income sources associated with a higher WI. Timber harvest in the study area is limited by (i) the lack of necessary equipment for timber harvest, but even more so by (ii) insufficient funds to "pay" relevant authorities for access because of (iii) legal restrictions. This is reflected in the very low number of respondents that identify timber as an important income source. Therefore, timber harvest has little potential for poverty alleviation in our study area given current local modes of forest governance.

While wildlife use would in principle be possible (the project area still holds habitat for wildlife), animal populations have largely disappeared due to over-hunting (Loucks et al., 2009). Moreover, many of the species used for consumption and traditional medicine are rare, with a potentially high risk of local extinction (WCS & TRAFFIC, 2004). In contrast to other regions where poorer households are highly dependent on wildlife as a source of protein and for traditional medicine (Walston, 2005), our results suggest that wildlife meat is mostly consumed out of taste preference. It is more expensive than domestic meat and is mainly consumed by wealthier households.

As wildlife hunting and utilisation of rare species are sensitive topics, we cannot exclude strategic reporting with respect to true utilisation, importance for income generation, and occurrence (e.g., Knapp et al., 2010). Pressures on wildlife from a few experienced and well-equipped hunters as well as from opportunistic hunting by villagers may still be tremendous. Based on villager statements, however, reliance on wildlife as an income generation strategy or as a source of protein was low, however. Therefore, more stringent law enforcement against illegal hunting may have acceptable impacts on local livelihoods.

Open access to less valuable resources: NTFP. — Our results suggest that NTFPs (excluding wildlife) are a more important and more frequently utilised source of income for poorer

households in comparison to households with relatively greater wealth. NTFPs were perceived to be more available, and there are less social mechanisms of exclusion because of their low relative value. Thus, poorer households take advantage, e.g., of fuel wood for sale or commercial charcoal production. In Indonesia or the Philippines, fuel wood, rattan, and bamboo were also shown to be preferentially used as a source of cash income by poorer households (Pattanayak et al., 2003; Pabuayon, 2004; Keil, 2004). Although perceived as relatively abundant, rattan and bamboo are rarely used as a source of cash income in the study region because of their low market value (Sedara et al., 2002). Similarly, resin collection contributes little to household income in the project region; however, this is more likely a result of the illegal logging of resin trees (and, hence, low availability) in the study region and other parts of Cambodia (Bottomley, 2000; Tola & McKenney, 2003).

RECOMMENDATIONS

While our results illustrate the importance of forest resources to villagers in the study area, it is clear that forest-based income generation (especially NTFP) has only a limited capacity to directly alleviate poverty. This is a result of the low accessibility of villagers to valuable resources and the underdeveloped market for NTFP products. Nevertheless, utilisation of forest resources may prevent villagers from falling into deeper poverty, and may serve an economic insurance function (e.g., Shackleton & Shackleton, 2004; Delacote, 2007). Since the local population relies on forest-based income generation and forest resource extraction, conservation and/or rural development initiatives should engage village communities near PKNP to participate in any future planning initiatives.

One example of combining biodiversity conservation and natural resource management are community forestry programs. Such programmes have received considerable attention in Cambodia and may be an approach that is suitable for our study site as well (Tola & McKenney, 2003). Community forestry initiatives have been successful in mitigating resource degradation and in conserving biodiversity; however, their ability to improve rural livelihoods will require addressing power inequalities among community stakeholder groups to ensure the equitable distribution of actual access to forest resources (Adhikari et al., 2004; Thoms, 2008). There is also evidence that community involvement and improved land tenure security in resource governance improves land and resource stewardship as well as sustainable forest and resource management provided that investments in local institutional development are made (Klooster, 1999; Dietz et al., 2003; Sunderlin, 2006; Menzies, 2007). In addition, community forestry initiatives can improve community organisation which can assist stakeholders in taking advantage of market opportunities and improve their power in and access to markets (Neumann & Hirsch, 2000). Furthermore, stricter law enforcement and protection of land ownership rights is needed to deter outside interests with the financial resources to exploit the more valuable forest products and displace local resource users.

While most interviewees were aware of negative impacts of forest conversion, income alternatives were limited though. To help decrease reliance on forest resources, sustainable development projects should focus on community capacity building in sustainable livelihoods and/or and marketable skills training (training in English, computer skills, and hospitality and nature guiding). Such programmes may include ecotourism as the Angkor region offers high potential because it is an important tourist magnet in SEA. Integrated agricultural practices such as home gardens or sustainable livestock rearing could be encouraged and agricultural productivity increased. For example, rice cultivation could be intensified, and the chamkars be developed into a mix of permacultures and sustainable agroforestry (Salafsky & Wollenberg, 2000; Lamb et al., 2005; Clough et al., 2011). However, capacity building programmes should be designed in close consultation with communities to ensure they reflect local communities' development needs and interests.

In conclusion, forest management initiatives should aim to facilitate community involvement in decision making and project implementation to be successful. Greater forest protection and resource stewardship is likely to be gained through projects such as community forestry, training in sustainable livelihood activities, and professional skill development. Integrating conservation and development objectives in this way will better promote income generation and help address poverty driven forest degradation and biodiversity loss. In addition, the government's decentralisation policy needs to be continued and combined with improved safeguards and more effective enforcement of land use regulations to address continued forest conversion. More effective law enforcement, however, will only be achievable when the highest levels of law enforcement lead this change (Nepstad et al., 2002; Agrawal et al., 2008). Finally, it is recommended that any community forestry initiatives adopt a landscape approach to help mitigate the displacement of activities to areas outside of community forests. Collectively, these suggestions will better enable and motivate PKNP communities to sustainably generate income while managing and protecting their resources.

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LITERATURE CITED

Adams, W. M., R. Aveling, D. Brockington, B. Dickson, J. Elliott, J. Hutton, D. Roe, B. Vira & W. Wolmer, 2004. Biodiversity Conservation and the Eradication of Poverty. *Science*, **306**: 1146–1149.

Adhikari, B., S. Di Falco & J. C. Lovett, 2004. Household characteristics and forest dependency: Evidence from common property forest management in Nepal. *Ecological Economics*, **48**: 245–257.

Agrawal, A., A. Chhatre & R. Hardin, 2008. Changing governance of the world's forests. *Science*, **320**: 1460–1462.

Amacher, G. S., W. Cruz, D. Grebner & W. F. Hyde, 1998. Environmental motivations for migration: Population pressure, poverty, and deforestation in the Philippines. *Land Economics*, **74**: 92–101.

Angelsen, A. & S. Wunder, 2003. *Exploring the Forest—Poverty Link: Key Concepts, Issues and Research Implications*. CIFOR Occasional Paper No. 40.

Barbier, E. B., 2004. Explaining Agricultural Land Expansion and Deforestation in Developing Countries. *American Journal of Agricultural Economics*, **86**: 1347–1353.

Barkmann, J., G. Burkard, H. Faust, M. Fremerey, S. Koch & A. Lanini, 2010. Land tenure rights, village institutions, and rainforest conversion in Central Sulawesi (Indonesia). In: Tscharntke, T., C. Leuschner, E. Veldkamp, H. Faust, E. Guhardja & A. Bidin (eds.), *Tropical Rainforests and Agroforests under Global Change. Ecological and Socio-Economic Valuations*. Springer, Berlin/Heidelberg. Pp. 141–160.

Bottomley, R., 2000. *Structural Analysis of Deforestation in Cambodia (with a Focus on Ratanakiri Province, Northeast Cambodia)*. Mekong Watch and Institute for Global Environmental Strategies, Japan. 36 pp.

Chandler, D., 2000. *A History of Cambodia*. Westview Press, Boulder. 312 pp.

Clough, Y., J. Barkmann, J. Juhrbandt, M. Kessler, T. C. Wanger, A. Anshary, D. Buchori, D. Cicuzza, D. Darras, D. Dwi Putra, S. Erasmi, R. Pitopang, C. Schmidt, C. H. Schulze, D. Seidel, I. Steffan-Dewenter, K. Stenchly, S. Vidal, M. Weist, A. C. Wielgoss & T. Tscharntke, 2011. Combining high biodiversity with high yields in tropical agroforests. *Proceedings of the National Academy of Sciences of the United States of America*, **108**: 8311–8316.

Colm, S., 1997. *Options for Land Security Among Indigenous Communities, Ratanakiri, Cambodia*. NTFP Project, Banlung, Cambodia.

Corlett, R. T., 2011. Impacts of warming on tropical lowland rainforests. *Trends in Ecology & Evolution*, **26**(11): 606–613.

Delacote, P., 2007. Agricultural expansion, forest products as safety nets and deforestation. *Environment and Development Economics*, **12**: 235–249.

Dietz, T., E. Ostrom & P. C. Stern, 2003. The struggle to govern the commons. *Science*, **302**(5652): 1907–1912.

Ferraro, P. J., M. M. Hanauer & K. R. E. Sims, 2011. Biodiversity Conservation and Poverty Traps Special Feature: Conditions associated with protected area success in conservation and poverty reduction. *Proceedings of the National Academy of Sciences*, **108**: 13913–13918.

Gaughan, A. E., M. W. Binford & J. Southworth, 2009. Tourism, forest conversion, and land transformations in the Angkor basin, Cambodia. *Applied Geography*, **29**: 212–223.

Gibson, L., T. M. Lee, L. P. Koh, B. W. Brook, T. A. Gardner, J. Barlow, C. A. Peres, C. J. A. Bradshaw, W. F. Laurance, T. E. Lovejoy & N. S. Sodhi, 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, **478**: 378–381.

von Grebmer, K., B. Nestorova, A. Quisumbing, R. Fertziger, H. Fritschel, R. Pandya-Lorch & Y. Yohannes, 2009. *Global Hunger Index: The Challenge of Hunger: Focus on Financial Crisis and Gender Inequality*. Deutsche Welthungerhilfe (German AgroAction), International Food Policy Research Institute, and Concern Worldwide, Bonn, Washington, D.C., and Dublin. 56 pp.

Hall, P. & K. Bawa, 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. *Economic Botany*, **47**: 234–247.

Hansen, K., & N. Top, 2006. *Natural Forest Benefits and Economic Analysis of Natural Forest Conversion in Cambodia*. Cambodia Development Resource Institute, Working Paper 33, Phnom Penh. 117 pp.

Hinrichs, A. & C. McKenzie, 2004. *Results of the Independent Review of Strategic Forest Management Plans Prepared by Concession Companies Operating in Cambodia*. GFA Terra Systems, Phnom Penh, Cambodia.

Hou, K., K. S. Rotha, L. Ung & S. Mao, 2004. *Management of Pilot Watershed Areas in Cambodia*. Working Paper 12 b. MRC-GTZ Cooperation Programme, Agriculture, Irrigation and Forestry Programme, Watershed Management Project (WSMP), Vientiane. 21 pp.

Kar, S. P. & M. G. Jacobson, 2012. NTFP income contribution to household economy and related socio-economic factors: Lessons from Bangladesh. *Forest Policy and Economics*, **14**: 136–142.

Keil, A., 2004. *The Socio-economic Impact of ENSO-related Drought on Farm Households in Central Sulawesi, Indonesia*. Gottingen University Dissertation. Shaker Verlag Aachen, Aachen, Germany. 214 pp.

Kim, S., N. Sasaki & M. Koike, 2008. Assessment of non-timber forest products in Phnom Kok community forest, Cambodia. *Asia Europe Journal*, **6**: 345–354.

Klooster, D., 1999. Community-based forestry in Mexico: Can it reverse processes of degradation? *Land Degradation & Development*, **10**: 365–381.

Knapp, E. J., D. Rentsch, J. Schmitt, C. Lewis & S. Polasky, 2010. A tale of three villages: Choosing an effective method for assessing poaching levels in western Serengeti, Tanzania. *Oryx*, **44**: 178.

IUCN & UNEP, 2009. *The World Database on Protected Areas (WDPA)*. UNEP-WCMC. Cambridge, UK. http://www.wdpa.org/Default.aspx.

Lamb, D., P. D. Erskine & J. A. Parrotta, 2005. Restoration of degraded tropical forest landscapes. *Science*, **310**: 1628–1632.

Lo Cascio, A. & R. Beilin, 2010. Of biodiversity and boundaries: A case study of community-based natural resource management practice in the Cardamom Mountains, Cambodia. *Environmental Conservation*, **37**: 347–355.

Loucks, C., M. B. Mascia, A. Maxwell, K. Huy, K. Duong, N. Chea, B. Long, N. Cox & T. Seng, 2009. Wildlife decline in Cambodia, 1953–2005: Exploring the legacy of armed conflict. *Conservation Letters*, **2**: 82–92.

Maertens, M., M. Zeller & R. Birner, 2006. Sustainable agricultural intensification in forest frontier areas. *Agricultural Economics*, **34**: 197–206.

McDonald, R. I., C. Yuan-Farrell, C. Fievet, M. Moeller, P. Kareiva, D. Foster, T. Gragson, A. Kinzig, L. Kuby & C. Redman, 2007. Estimating the effect of protected lands on the development and conservation of their surroundings. *Conservation Biology*, **21**: 1526–1536.

McKenzie, D. J., 2004. *Measuring Inequality with Asset Indicators*. BREAD working paper No. 42. Bureau for Research and Economic Analysis of Development, Cambridge.

Menzies, N. K., 2007. *Our Forest, Your Ecosystem, Their Timber: Communities, Conservation, and the State in Community-Based Forest Management*. Columbia University Press, New York. Pp. 449–451.

NASA, 2005. *World Wind 1.4.* www.worldwind.arc.nasa.gov/.

Nepstad, D., D. McGrath, A. Alencar, A. C. Barros, G. Carvalho, M. Santilli & M. D. V. Diaz, 2002. Enhanced: Frontier governance in Amazonia. *Science*, **295**: 629–631.

Neumann, R. P. & E. Hirsch, 2000. *Commercialization of Non-timber Forest Products: Review and Analysis of Research.* Centre for International Forestry Research, Bogor. 173 pp.

NGO Forum Forestry Project, 2003. *Sector Paper on Forestry in Cambodia*. Phnom Penh.

NIS, 2008. *General Population Census of Cambodia 2008*. Provisional Population Totals. National Institute of Statistics, Ministry of Planning, Phnom Penh.

Pabuayon, I. M., 2004. Consumption value and income potential of bamboo in the Philippines: Evidence from selected areas and case studies. *Journal of Bamboo and Rattan*, **3**(3): 249–263.

Pattanayak, S. K., E. O. Sills, A. D. Mehta, & R. A. Kramer, 2003. Local uses of parks: Uncovering patterns of household production from forests of Siberut, Indonesia. *Conservation and Society*, **1**: 209–222.

Paumgarten, F. & C. M. Shackleton, 2011. The role of non-timber forest products in household coping strategies in South Africa: The influence of household wealth and gender. *Population and Environment*, **33**: 108–131.

Peluso, N. L., 1992. *Rich Forests, Poor People: Resource Control and Resistance in Java*. University of California Press, Berkeley, California. 336 pp.

R Development Core Team, 2011. R: A language and environment for statistical computing. *Foundation for Statistical Computing*, Vienna, www.R-project.org/.

Ra, K., L. Pichdara, Y. Dararath, X. Jiao & C. Smith-Hall, 2011. *Towards Understanding Household-level Forest Reliance in Cambodia–Study Sites, Methods, and Preliminary Findings*. Forest & Landscape, Denmark. Working Papers no. 60. 120 pp.

Rasul, G. & G. B. Thapa, 2003. SC in the mountains of South and Southeast Asia: Regional patterns and factors influencing the change. *Land Degradation and Development*, **14**(5): 495–508.

Salafsky, N. & E. Wollenberg, 2000. Linking livelihoods and conservation: A conceptual framework and scale for assessing the integration of human needs and biodiversity. *World Development*, **28**: 1421–1438.

Sedara, K., T. Sophal & S. Acharya, 2002. *Land, Rural Livelihoods and Food Security in Cambodia*. Cambodia Development Resource Institute, Phnom Penh.

Shackleton, C. M. & S. E. Shackleton, 2004. The importance of non-timber forest products in rural livelihood security and as safety-nets: A review of evidence from South Africa. *South African Journal of Science*, **100**: 658–664.

Sodhi, N. & B. W. Brook, 2006. *Southeast Asian Biodiversity in Crisis*. Cambridge University Press, Cambridge. 51 pp.

Sodhi, N. S., G. Acciaioli, M. Erb & A. K.-J. Tan, 2008. *Biodiversity and Human Livelihoods in Protected Areas: Case Studies from the Malay Archipelago*. Cambridge University Press, Cambridge, UK. 478 pp.

SPSS, 2005. *SPSS 14.0 for Windows*. Rel. 14.0.4 SPSS Inc., Chicago.

Sunderlin, W. D., 2006. Poverty alleviation through community forestry in Cambodia, Laos, and Vietnam: An assessment of the potential. *Forest Policy and Economics*, **8**: 386–396.

Sunderlin, W. D., A. Angelsen, B. Belcher, P. Burgers, R. Nasi, L. Santoso & S. Wunder, 2005. Livelihoods, forests, and conservation in developing countries: An overview. *World Development*, **33**: 1383–1402.

Thoms, C. A., 2008. Community control of resources and the challenge of improving local livelihoods: A critical examination of community forestry in Nepal. *Geoforum*, **39**: 1452–1465.

Tola, P. & B. McKenney, 2003. T*rading Forest Products in Cambodia: Challenges, Threats, and Opportunities for Resin*. Working Paper 28. CDRI, Phnom Penh.

Tscharntke, T., C. Leuschner, M. Zeller, E. Guhardja & A. Bidin (eds), 2007. *The Stability of Tropical Rainforest Margins, Linking Ecological, Economic and Social Constraints of Land Use and Conservation*. Springer Verlag, Berlin. 513 pp.

Turton, C., 2000. *The Sustainable Livelihoods Approach and Programme Development in Cambodia*. ODI, London.

UNCED, 1992. *Report of the United Nations Conference on Environment and Development (Rio de Janeiro, 3–4 June 1992)*. A/CONF. 151/26 (Vol. III).

UNDP (United Nations Development Program), 2010. *Cambodia—Annual Report 2010. Empowered Lives*. Resilient Nations. Phnom Penh, Cambodia

Vedeld, P., A. Angelsen, J. Bojo, E. Sjaastad & G. K. Berg, 2007. Forest environmental incomes and the rural poor. *Forest Policy and Economics*, **9**: 869–879.

Walston, N., 2005. *An Overview of the Use of Cambodia's Wild Plants and Animals in Traditional Medicine Systems.* TRAFFIC Southeast Asia, Greater Mekong Programme, Ha Noi, Viet Nam.

WCS (Wildlife Conservation Society) & TRAFFIC, 2004. *Hunting and Wildlife Trade In Asia: Proceedings of a Strategic Planning Meeting of the Wildlife Conservation Society (WCS) and TRAFFIC, Bali, Indonesia*. WCS and TRAFFIC, Kuala Lumpur.

World Bank, 2006. *Cambodia: Halfing poverty by 2015?* World Bank, Phnom Penh

World Bank, 2009. *Poverty Profile and Trends in Cambodia 2007: Findings from the Cambodia Socio-Economic Survey (CSES), East Asia and the Pacific Region.* World Bank, Phnom Penh.

Wunder, S., 2001. Poverty alleviation and tropical forests—What scope for synergies? *World Development*, **29**:1817–1833.

Yemiru, T, A. Roos, B. M .Campbell & F. Bohlin, 2010. Forest incomes and poverty alleviation under participatory forest management in the Bale Highlands, Southern Ethiopia. *International Forestry Review*, **12**: 66–77.

Zeller, M., M. Sharma, C. Henry & C. Lapenu, 2006. An operational method for assessing the poverty outreach performance of development policies and projects: Results of case studies in Africa, Asia, and Latin America. *World Development*, **34**: 446–464.

APPENDIX 1: QUESTIONNAIRE

Date: ……...

Village: ……... Commune: ……

Male / Female GPS coordinate: ……

Household characteristics:

1) How many people are in your household? ……

2) How many males at the age of:
0–5 ..... 5–10 ……. 10–15 ..... >15 ……. >55 .....

How many females at the age of:
0–5 ..... 5–10 ……. 10–15 ..... >15 ……. >55 .....

3) How many Motorbikes: …… Bikes: ……. Cars: ….…… Tractors ……...do you have?

4) Do you use a stove which burns less wood/charcoal? Y / N – Circle which one.

5) Is your family from this village (born here)?
If NO: When did you move here (year)?
If NO: Was the reason you moved here to have better access to forest resources? Y/ N

6) Do any household members speak English? Y/ N
For each English speaking family member circle English abilities which apply:
Read / Write / Poor Speaker / Good Speaker

Land holdings:

7) Please the check the boxes relevant to your household's land holdings.

Kind of Land Holding	Own	Rent	Size (Ha)
House	☐	☐	
Permanent rice field	☐	☐	
Chamkar	☐	☐	
Other agricultural field	☐	☐	
Unused forest land	☐	☐	
Other	☐	☐	

8) What do you grow on your Chamkar (Plantation burned from Forest)?

9) If you have a chamkar, how many years can crops grow before you have to cut a new chamkar?

10) How many years does your agricultural land stay fertile?

Occupation and skills information:

11) Please give information on your household's major cash income, and rank its importance.

Income category	Income source	Rank
Agriculture	Rice	
	Chamkar	
	Other crops	
	Palm sugar	
	Others:	
Livestock	Cow	
	Pig	
	Chicken	
	Buffalo	
	Others:	
Forest Products	Timber	
	Fire wood	
	Non-timber forest product	
	Charcoal	
Hunting	Selling wildlife	
Fishing	Catch fish	
	Raise fish	
Labour		
Small Business		
Other		

Skills:

12)Please check relevant boxes or list any other skills or job experience household members have.

Skills	Have been trained before (Check box if Yes)	Scale of knowledge		
		Know a little	Can use knowledge themselves	Can teach others
Honey collector	☐	☐	☐	☐
Electrician	☐	☐	☐	☐
Auto/motor mechanic	☐	☐	☐	☐
Making baskets/mats	☐	☐	☐	☐
Tree species identification	☐	☐	☐	☐
Making furniture	☐	☐	☐	☐
Nursery techniques and tree planting	☐	☐	☐	☐
Forest fire prevention and forest fire breaks	☐	☐	☐	☐
Official report writing	☐	☐	☐	☐
Accounting/budget management	☐	☐	☐	☐
Resin collector	☐	☐	☐	☐
Forest mapping	☐	☐	☐	☐
Forest management	☐	☐	☐	☐
Forest product harvesting	☐	☐	☐	☐
Forest product processing	☐	☐	☐	☐
Forest product marketing	☐	☐	☐	☐
Palm juice collection	☐	☐	☐	☐
House construction	☐	☐	☐	☐
Roof making	☐	☐	☐	☐
Other…….	☐	☐	☐	☐

Forest resource patterns:

13) Please list the most significant forest products for your livelihood and how those products are available from the forest. (Use the availability scale below, choose importance using the scale).

Scale 1–7	
1–3: hard to find 4–5: available 6–7: easy to find	

Forest product	Availability compared to 5 years ago	For sale (cash income)	For family use (subsistence)	Stopped selling

14) How many resin tapping trees do you have?
How did you get those trees? Check all that apply

☐ Inherited ☐ Bought
☐ Customary rights ☐ Others …….....

15) Has your household been negatively impacted by decreasing availability of forest products? Y / N
a) Please list which decreasing forest products have negatively impacted the household:
b) How or why has this negatively impacted your household?

16) Is there a problem with cutting down trees to collect forest products? Y / N

a) If YES: Which products are harvested by cutting down the tree? List which fruit trees:
b) Which groups do the cutting:

☐ Military ☐ Police ☐ Outsiders
☐ Villagers ☐ Other……

17) Are there any issues among villagers concerning access to forest resources? Y / N
(If YES) What causes these issues?

18) Who in the village has the most access to the forest and its resources? Why do you think this is?

19) How often do you notice people from outside this village taking village forest resources?

☐ All the time (1–3 times a week)
☐ Very often (1–3 times every two weeks)
☐ Often (1–3 times a month)
☐ Sometimes (1–3 times every 3 months)
☐ Almost never (1–3 times a year)
☐ Never

20 a) Do you know who the outsiders are?
b) What do they take?

☐ Timber ☐ Wildlife ☐ Resin ☐ Charcoal
☐ Foods ☐ Fire wood ☐ Others……

c) Do you think this is a problem?

Wildlife use:

23) How often does your household consume forest animals?

- ☐ All the time (1–3 times a week)
- ☐ Very often (1–3 times every two weeks)
- ☐ Often (1–3 times a month)
- ☐ Sometimes (1–3 times every 3 months)
- ☐ Almost never (1–3 times a year)
- ☐ Never

24) Please list the five most frequently eaten wildlife items:

25) Why do you eat wildlife instead of livestock meat items? Does wildlife cost more or less than livestock?

26) Do you use traditional medicines made from wild animals? Y / N
Please list any animal products and their uses and whether there is a reason you use these medicines instead of medicines you can get from a pharmacy?

27) Have you noticed a decrease over the last five years in:

- ☐ Pangolin
- ☐ Loris
- ☐ Hornbill
- ☐ Turtle
- ☐ Sunbear
- ☐ Wild pig
- ☐ Muntjac
- ☐ Gibbon
- ☐ Silver Langur
- ☐ Stumptailed Macaque

Scale 1–7	
1–3: hard to find 4–5: available 6–7: easy to find	

Environmental issues:

28) Are you aware of any environmental problems created by deforestation? Y / N
Please list any comments:

APPENDIX 2: VARIABLE CONSTRUCTION

To analyse the town-forest gradient, the variable "distance" was computed from the GPS measurements of each household. It represents the distance gradient to Siem Reap as villages and households stretch linearly along the National Road 67.

The variable "years" are the years the respondent is already in living in the area (question 5, Appendix 1) with 30 years as set value appointed to the native respondents.

The variables for the multinomial logit model selection (distance, WI, and years) were selected based on experience in the study area and relevance for a typical forest frontier situation.

In order to understand the forest resource use patterns, respondents were asked to list the resources they extract from the forest and state how they dominantly utilise them (answers were categorised as "sale", "family use", and "stopped selling"). We used this information to construct the binary categorical variables (1=yes, 0=no) "collection of forest resources", "extracting timber for subsistence", and "extracting fuel wood for subsistence":

Also binary categorical variables (1=yes, 0=no) were "wildlife consumption", and "traditional medicine use".

To determine the perceived availability of wildlife or forest resources, we used a seven-point Likert scale, ranging from "hard to find" to "easy to find".

SUPPLEMENTARY MATERIAL

Table S1. Additional characteristics of the surveyed communities in Table 1. Standard deviations (SD) are given in brackets. Other permanent land refers to agricultural land not including rice fields and chamkars (like lemon or mango orchards).

	Komprom (KP-1)	Kundriem (KR-2)	Kna Rung Veas (KRV-3)	Tout Kru (TK-4)	Total
Distance to Siem Reap /km	39.5	41.7	44.3	50.4	
Number of households interviewed	54	40	35	20	149
Ownership of other permanent land /%	1.9	10	8.6	0	5.4
Other permanent land size /ha	0.8	1.1 (± 0.7)	3.0(± 2.6)	0	1.8 (± 1.8)
Ownership of unused forest land /%	0	7.5	17.1	0	6.0
Unused forest land size /ha	0	2.7 (± 2.1)	2.6 (± 1.5)	0	2.6 (± 1.6)

Table S2. List of wildlife species used for consumption, traditional medicine, and the cure and preparation of these animals. We are aware of the possible caveats regarding use of secondary information to verify the type of wildlife involved. For species, where we could not attribute the scientific species name with confidence more general groups (e.g., deer, snake) are given.

Species	Scientific name (if possible)	Number of respondents using wildlife for	Number of respondents using consumption wildlife for traditional medicine	Cure
Deer		81	2	Cures broken bone
Wild pig	*Sus scrofa*	82	1	Makes people healthy
Monitor lizard	*Varanus* sp.	13		
Burmese hare	*Lepus peguensis*	13	3	Cures infected eyes
Turtle		9		
Snake		2	3	Cures baby with birth mark on body, reduces swelling from infection, makes people strong
Palm civet	*Paradoxurus hermaphroditus*	9		
Hog badger	*Arctonyx collaris*	1	1	Makes woman healthy after they gave birth
Malayan porcupine	*Hystrix brachyura*	10	13	Makes woman healthy after they gave birth
Indochinese silvered langur	*Trachypithecus germaini*	1	1	Makes woman healthy after they gave birth
Sunda pangolin	*Manis javanica*	1	4	Makes woman healthy after they gave birth, cures itchy skin
Asian slow loris	*Nycticebus bengalensis*	11		Cures malaria, stomach pain, diarrhoea, makes woman healthy after they gave birth
Indo-Chinese tiger	*Panthera tigris corbetti*		2	Makes people strong
Chinese serrow	*Capricornis milneedwardsi*		4	Makes woman healthy after they gave birth, heals wounds and snake bites

Fig. S1. Perceived availability of different wild animals. 0 = not there anymore, rank 1 = very hard to find, rank 7 = very easy to find. Error bars display the SD. Because species identification was done verbally (without pictures) we asked for charismatic and commonly known species (for details see Tab. S2). Numbers above error bars represent sample size (n).