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Stable Forest Cover under Increasing Populations of Swidden Cultivators in Central Laos: the Roles of Intrinsic Culture and Extrinsic Wildlife Trade

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ABSTRACT. Swidden agriculture, or shifting cultivation, is variously viewed as a great environmental threat or a sustainable system of land use. In Laos, swidden has long been considered the primary driver of forest loss nationwide, but the assessment is based exclusively on studies from the north of country, where deforestation is most severe. National policies to control swidden have percolated down to management of one of the largest nature reserves in the region, Nakai-Nam Theun National Protected Area (NNT NPA) in the Annamite Mountains of central Laos. In NNT NPA, swidden's presumed unsustainability and deleterious impact on forest cover is an untested assumption. We tested it by methods of historical ecology, tracing the patterns of NNT's forest cover and human settlement over the past several decades. Principal sources of data were topographical maps dating to 1943, and Landsat images from 1976, 1989, and 2001.

The analysis shows that, although NNT has been inhabited by swidden cultivators for hundreds of years, it retained more than 95% forest cover until the 1960s–early 1970s. Subsequently, a post-Vietnam War release of human population, possibly coupled with government encouragement of agricultural expansion, precipitated a decline in forest of 0.5%/year until the 1980s. Curiously, this was followed by stability or an increase (ca. 0.3%/year) in forest cover into the current century, even as NNT's human population continued to grow and as forest declined in Laos overall at 1.7%/year, and in two protected areas near NNT at more than 3%/year.

A combination of intrinsic and extrinsic factors probably account for the stability of NNT's forest cover despite recent population growth. First are cultural propensities for sedentariness and livelihoods with relatively low environmental impact among the ethnic groups inhabiting NNT. Since at least the 1940s, there have been remarkably few changes in the number or location of villages in NNT (and despite upheavals during the Vietnam War). Clearly, "shifting cultivation" is not equivalent to shifting populations. The extent of cleared forest in NNT has remained almost entirely within a swidden–forest mosaic whose boundaries date back at least to the 1960s. Second, the last 20 years have seen an explosion in wildlife trade in the region, particularly of animals valued in traditional medicine. Income earned from wildlife trade may have allowed NNT's residents to purchase rice to feed growing populations, instead of clearing more forest to grow it.

The situation presents a dilemma for conservationists—attempts to control local wildlife trade could push NNT's villagers to clear more forest swiddens, and vice versa. Controlling both simultaneously would probably have a negative impact on villagers' standard of living. As wildlife trade is a greater threat to NNT's biodiversity values than local systems of rotational swidden, management should focus first on reducing wildlife trade. In any case, forest conservation (and villagers' welfare) will benefit more from alleviation of of NNT's human population growth than control of its traditional agriculture; it was primarily a shift in demography, not in agricultural practices, that precipitated the post-war period of forest loss. Finally, attempts to reduce local access to swidden land should come only after better understanding of the current swidden systems is achieved, and proven alternatives have been established.

Key Words: *Annamite Mountains; Brou; Cuora trifasciata; Dalbergia; deforestation; historical ecology; Lao PDR; Manis; Nakai-Nam Theun; Nam Theun 2; pangolin; Pseudorxy nghetinhensis; saola; Sek; shifting cultivation; slash and burn; sustainable agriculture; swidden agriculture; Vietic*

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INTRODUCTION

Southeast Asia has the highest deforestation rate in the world, about twice that of Africa or South America (Achard et al. 2002, Lepers et al. 2005). The loss is generally attributed to three main causes: (1) commercial logging, (2) commercial crop plantations, and (3) swidden agriculture, also known as "shifting cultivation" or "slash and burn" (Terborgh 1992, Dove 1993, Kummer and Turner 1994, Brady 1996). Although logging and commercial agriculture are universally recognized as detrimental to the region's forests and biodiversity, there is less consensus on the impact of traditional swidden agriculture. Conklin (1957) defined swidden as any agricultural system with two characteristics: (1) burning to prepare fields for planting and (2) the period of cultivation shorter than the period of fallow regeneration. Assessments of swidden have ranged from "an environmentally and economically unsuitable practice" (Rasul and Thapa 2003) to "...an extravagant and unscientific form of land use... [t]he evil effects of shifting cultivation are devastating and far-reaching in degrading the environment" (Ranjan and Upadhyay 1999) to "a sustainable form of land-use, compatible with specific conservation goals" (Raman 1996) to "the most efficient and proven method of agriculture in many of the world's tropical habitats" (Netting 1986).

Swidden is widely practiced in the country of Laos (in this paper we use "Laos" for the geographic entity and the country's official name, Lao People's Democratic Republic or Lao PDR, for the political entity). Nonetheless, the country retains among the highest proportion of forest cover of Southeast Asian nations, recently estimated at 41.5% of land area (Government of Lao PDR 2005), although this represents a significant decline in the past few decades—70% of the country was probably forested in the 1940s (Baker et al. 2000). The Government of Lao PDR (GoL), encouraged by some international donors, has routinely denounced swidden as the primary threat to the country's forests. Consequently, the GoL's foremost national land-use policy in the 1990s was to eliminate swidden cultivation by the year 2000 (Fujisaka 1991). When this proved too ambitious, the GoL aimed to "stabilize" swidden by the year 2010 (Ministry of Agriculture and Forestry (MAF) 2003).

However, all published studies of swidden in Laos are from its northern provinces, where deforestation has been most severe, driven by a particular confluence of history, ethnicity, and population density (e.g., nearly all of Laos's population of Hmong, who tend to be efficient and nomadic pioneering shifting cultivators, live in the north). Perhaps understandably, Lao swidden systems have been studied where they appear most damaging. Areas of the country where swidden systems might approach sustainability—and where perhaps lie important lessons for ecological resilience—have had scant research attention. Possibly, lessons have been taken only from the failures, not the successes.

Qualitative observations by the senior author while working intermittently over several years in Laos's largest nature reserve, Nakai-Nam Theun National Protected Area (NNT NPA) in central Laos, indicated that the link between swidden and deforestation in the reserve is, at best, complex. About 6000 people live in NNT NPA; the area has been inhabited for at least hundreds of years and swidden is fundamental to local subsistence, yet the area retains extensive forest cover, including good quality forest near the edges of many villages. We endeavored to reconcile these characteristics through the following research questions:

1. Has forest cover changed in NNT NPA in recent decades? If so, what has been the magnitude and direction of the change, in particular compared with Laos as a whole?

2. What have been the principal drivers of any change in forest cover (or stability) in the area?

In short, the purpose of this research is to attempt to quantitatively confirm or refute a qualitative impression of sustainability of swidden cultivation in NNT NPA.

Nakai-Nam Theun National Protected Area is the largest of Laos's 20 national protected areas. It covers about 3500 km^2 of mostly dense forest in the Annamite Mountains along the border with Vietnam (Figs. 1 and 2). Not only is it the largest protected area in either country, it is the most important for biodiversity conservation, and one of the most important nature reserves in Asia (Robichaud et al. 2001). Its conservation significance comes from the extent and quality of its forest cover, its diversity of biota (e.g., more than 400 species of birds recorded

thus far), and the fact that it is the largest protected area in the world harboring several threatened vertebrates endemic to the Annamites, including large mammals such as the large-antlered muntjac, *Muntiacus vuquangensis*, and the saola, *Pseudoryx nghetinhensis*, (Fig. 3).

Nakai-Nam Theun's human diversity is equally impressive. None of its residents are ethnic Lao, but belong to various ethnic groups speaking about 20 languages in four major language families; some of the languages are endemic to NNT and have only come to the attention of linguists since the late mid-1990s (Chamberlain et al. 1996). Human habitation of NNT has a long history. The most recent inhabitants probably arrived well over a century ago (Anonymous 2005), and the original inhabitants surely much longer ago than this (Chamberlain et al. 1996). Residents typically live in isolated villages (Fig. 4), around which they practice various forms of subsistence agriculture, primarily swidden cultivation of glutinous rice (Fig. 5), supplemented by fishing and extensive foraging for wild plant and animal foods. Gazettement of the site as a national protected area (NPA) has had little impact on traditional livelihoods; by GoL policy, villagers in NPAs will not be forcibly relocated, and they retain rights to traditional use of local natural resources. Population growth rates are high in the protected area, estimated in excess of 3% per year, and possibly up to 4% in some villages (Alton and Sylavong 1997), compared with 2.2% for Laos as a whole (United Nations Development Programme (UNDP) 2004a).

In part due to its biological and cultural significance and in part to its proximity to a large, new hydroelectric dam project (the Nam Theun 2, whose construction just outside the protected area is nearly complete), NNT has been the focus of intense management planning for many years (Wildlife Conservation Society (WCS) 1995a,b, 1996, International Union for Conservation of Nature (IUCN) 1997, 1998a,b, 1999, Seatec International 2000, Watershed Management and Protection Authority (WMPA) 2004, 2005). A prominent thesis in many of these documents is that swidden cultivation by indigenous residents is a major threat to the area's forest cover, and replacing traditional swidden systems with fixed rice paddies or fixed-plot cash cropping is a priority for management of the protected area. This is an assumption not always supported by observations on the ground, and the fundamental aim of this study is to test this assumption.

METHODS

We determined the magnitude and direction of forest-cover change in NNT NPA through analysis of a series of topographic maps and satellite images. We evaluated the possible drivers of any observed change through interviews with residents of NNT NPA, field observations, and examination of secondary sources such as protected area survey reports.

For the geographic study, our area of analysis is the main block of NNT NPA excluding fringes on the adjacent Nakai Plateau (which has seen significant salvage logging for the nearby dam). This area of analysis covers 308 465 ha. We analyzed paper topographic maps and Landsat imagery separately, one as a check of the other, in a two-step, sequential process. First, we examined patterns of forest change as shown by topographic maps, which reach back farther in time than Landsat and are more detailed but less consistent (e.g., scale variation among different map series), and next from the more recent, less detailed, but more uniform Landsat data. Together, they span 36 years.

Map Analysis

We obtained copies of all known series (four) of topographic maps that cover NNT NPA. Three show enough detail for habitat analysis: 1960s U.S. Army Map Service 1:50 000, 1981 GoL PDR 1:100 000, and 1992–1993 GoL PDR and Japan 1:25 000. The 1992–1993 series covers only about 55% of NNT. We scanned the map sheets and digitized them in ArcView® 3.2 and 3.3 for all significant habitat features and village locations. Because the maps were produced by different institutions, using different data and projections, and at different scales, some manipulation was required to make them comparable. During the scanning process, we transformed the maps to match the datum, Indian 1960, and projection of the 1960s maps. Because the maps use broadly similar but not identical habitat classifications, we lumped habitat classes into more general categories of "forest" (e.g., dense and open forest) and "non-forest" (e.g., scrub, cultivation). Finally, early village locations were plotted from maps published by the French Indochina colonial administration in 1943.

The most serious constraint to comparison of the maps was their difference in scale. The principal consequence of scale variation is variation in the

Fig. 1. Lao PDR and Nakai-Nam Theun National Protected Area.

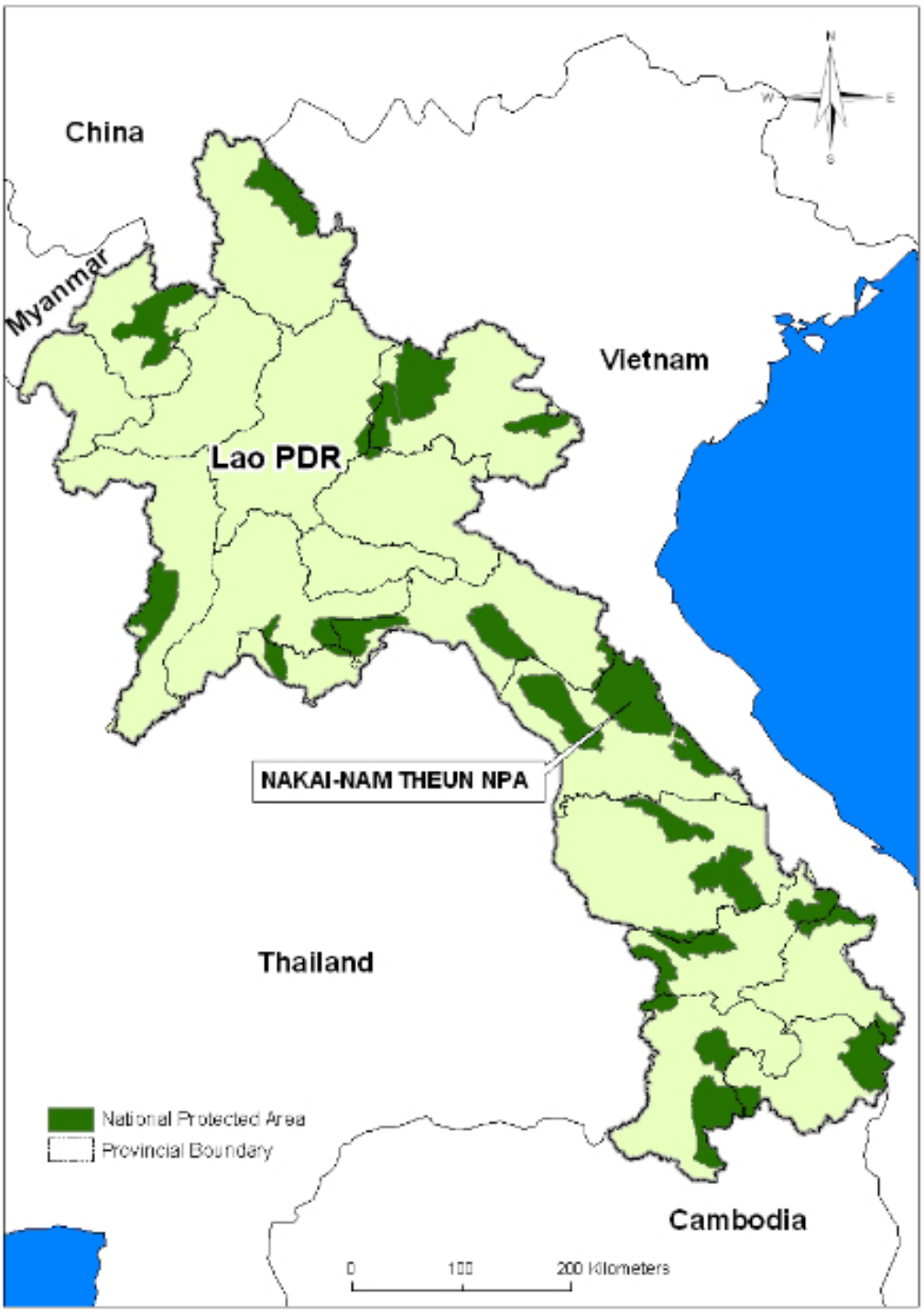


Fig. 2. Forest of Nakai-Nam Theun National Protected Area.

Fig. 3. One of the only photographs of the saola (*Pseudoryx nghetinhensis*), a bovid endemic to the Annamite Mountains along the Laos–Vietnam border; photographed by camera-trap near Nakai-Nam Theun National Protected Area.

minimum mapping unit (MMU), the size of the smallest habitat polygon that a cartographer will draw to distinguish one habitat patch from another. On most maps of NNT, forest is the background "default," within which are delimited polygons of non-forest areas. Smaller-scale maps have coarser resolution and thus larger MMU polygons than do larger-scale maps. We compensated for this in two ways. First, we determined the size of the MMU on the smallest scale maps (1:100 000), and then deleted from the other maps all habitat polygons smaller than this. Second, on the two larger-scale maps, we replicated the cartography of the smaller scale 1:100 000 maps by a process of combining clusters of separate, neighboring polygons of the same habitat type into single, large polygons. This replicated the appearance of the 1:100 000 maps. This homogenization process was somewhat subjective (e.g., in determining the boundary of a "cluster" of like polygons), but it may have been

Fig. 4. Visitors entering an ethnic Brou village (Ban Kunae) in Nakai-Nam Theun National Protected Area, with swidden/forest mosaic visible beyond the village (2008).

equally subjective for the cartographers of the 1:100 000 maps. In any case, maps were analyzed as is and with this correction, and we assume that reality lies between the two.

The impact of forest-cover change depends not only on how much forest, if any, has been lost, but also where. Has clearing been intense and localized within a relatively fixed area of the forest/non-forest mosaic, or has it been diffuse and widespread, affecting a much larger area? To analyze this we used the method of convex hulls. A convex hull is a polygon drawn around a cluster of points, such that it encloses all points within the minimum total length of segments (a rubber band stretched around a group of protruding nails would form a convex hull). Using an algorithm known as "Jarvis' march" or "gift wrapping" (Hausner 2005), we drew convex hulls around the cleared areas surrounding NNT's concentrations of settlements in each of its main stream valleys, as shown on the 1960s maps (Fig. 6). We ignored natural clearings such as rock outcrops, the clearing along the edge of the Nakai Plateau and, to aid comparison, clearings smaller than the MMU on the coarser-scale 1981 maps. This yielded four convex hulls, which we then laid over

Fig. 5. Swidden rice field, after harvest (cleared by ethnic Brou, near Ban Kunae village); Nakai-Nam Theun NPA (2008).

the results from the 1981 maps (Fig. 7) to assess the stability of the boundaries of the 1960s forest/non-forest mosaic (note: the 1992–1993 map series does not cover enough of this area of analysis to allow a similar comparison).

Landsat Analysis

We acquired Landsat scenes covering most of NNT (excluding an uninhabited corner of the reserve, about 17% of the area of analysis) in band sequential (BSQ) format from three epochs: 1976 (Landsat 2 MSS), 1989 (Landsat 5 TM), and 2001 (Landsat 7 ETM). Landsat imagery matching the same years as the maps was not available (namely, no Landsat in the 1960s, and very little available covering NNT in the 1980s). We chose 2001 as the endpoint to ensure capturing a picture of traditional agricultural systems, before possible influence by government swidden control programs. We georectified the scenes to match the topographic maps and classified them with PCI Geomatics Geomatica® Version 9.1. The resolution of the Landsat platforms varied: 60 x 60 m or 0.36 ha per pixel for 1976 MSS, and 30

Fig. 6. Convex hulls drawn around the 1960s-era forest/non-forest mosaic in Nakai-Nam Theun National Protected Area's populated stream valleys.

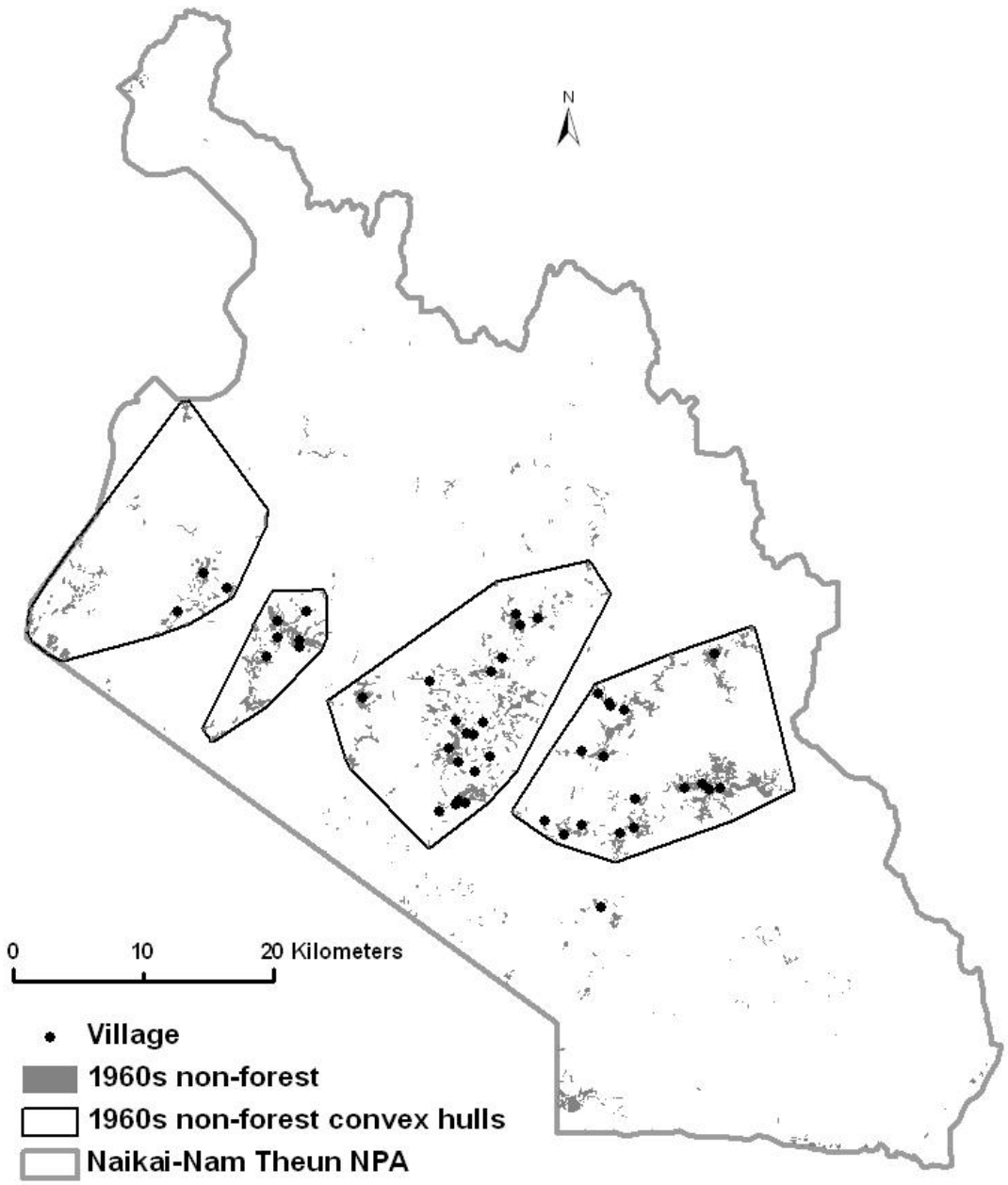
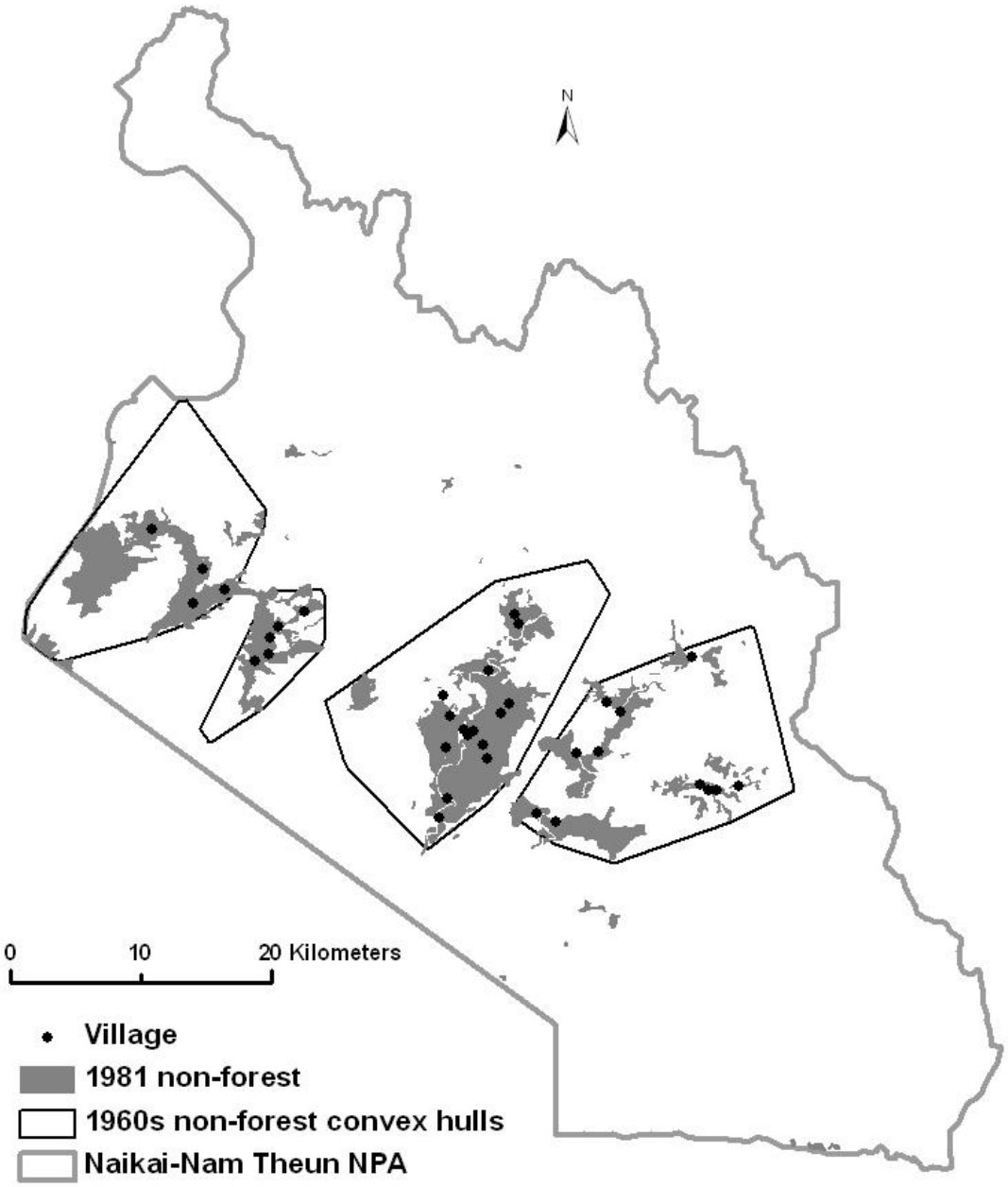


Fig. 7. 1960s convex hulls superimposed on the 1981 forest/non-forest mosaic in Nakai-Nam Theun National Protected Area's populated stream valleys.



m x 30 m or 0.09 ha per pixel for the later platforms. To correct for this and to achieve a common resolution, we filtered the scenes with PCI Modeler's SIEVE® translation algorithm for 8 pixels at the 0.36-ha pixel resolution (1976) and 32 pixels at the 0.09-ha resolution (1989 and 2001). The result was a common pixel resolution of 2.88 ha for all scenes, which the algorithm achieved by merging pixel polygons smaller than this threshold with their largest neighbors.

Variation in the season of acquisition (dry vs. wet) of suitable sets of Landsat scenes, plus a lack of aerial photographs or an opportunity to groundtruth after selection of the training sites, dictated a conservative classification. We sacrificed detail for accuracy, by using a supervised classification to distinguish just two habitat types, forest and non-forest (as with the maps). Natural clearings, such as rivers, sandbanks and rock outcrops were grouped with "forest." Training sites were selected based on the senior author's extensive firsthand knowledge of NNT. In effect, training sites were partially groundtruthed in advance. The maps also aided in corroborating the training sites. For example, agricultural areas shown on the 1981 topographic maps were considered unlikely to be "forest" just 8 years later on 1989 Landsat scenes.

Calculations

For both maps and satellite data, areas of polygons of non-forest in each period of analysis (three periods for each) were summed in ArcView 3.3.

The instantaneous, annual rate of change in forest cover between each sample period within each watershed was then calculated by:

$$r = [\ln(A_2 / A_1)] / (T_2 - T_1) \quad (1)$$

where:
r = annual rate of change
A_1 = proportion of forest area to total area at time T_1
A_2 = proportion of forest area to total area at time T_2
T_1 = first year of sample period
T_2 = last year of sample period

Interviews

Residents of NNT NPA were interviewed at various times between 1995 and 2008. Most interviews were held in the residents' homes, but others were held in survey camps in the forest or in the course of forest walks. All major ethno-linguistic groups in the protected area were represented. There was bias toward interviewing adult men because the principle topics of interest, forest clearance and hunting, are primarily male roles. Interviews were in the Lao language, which is the second language of NNT's villagers but in which most adult men are fluent. The discussions included both informal, wide-ranging exchanges and semistructured interviews on specific topics, following elements of the approach described by Steinmetz (Steinmetz 2000). Given that many interviews were informal and opportunistic, a precise count of participants was not kept, but there were more than one hundred. Although many interviews did not specifically target the research questions of this paper (in fact, such interviews helped generate the research questions), most dealt with issues of local natural resource use, and thus often served to illuminate the topic at hand, often in unanticipated ways. Interviews also allowed collection of information on areas of the protected area not visited, or history not seen. Additional interviews and discussions on the specific research questions were held with biologists, anthropologists, and government staff who have worked in NNT NPA.

Field Observations

One of us (Robichaud) has worked intermittently in NNT since 1995, on both wildlife surveys and various issues of protected area management. He has visited all of NNT's villages and most of its major forest blocks, some of them more than once over intervening spans of more than a decade.

Secondary Written Sources

All known, English-language, written sources on social and ecological aspects of NNT NPA were reviewed. Most of these are "gray" literature reports written by consultants or by staff of international non-governmental organizations in Laos.

RESULTS

Table 1 shows, for the full area of NNT NPA covered by the 1960s and 1981 topographic maps, the extent of forest cover and its annual rate of change, *r* (expressed as a percentage), both corrected and uncorrected for map scale differences, and the mean of the two results. Table 2 shows the same for the reduced portion of NNT covered by the 1992–1993 map series. The human–forest dynamics of NNT might be obscured or diluted in these analyses by inclusion of a remote site with no villages, the middle and upper Nam On river watershed, which comprises the south end of the reserve and nearly a quarter of the area of analysis. This large area has been inhabited by only a few forest-based hunter–gatherers (and is insulated from logging or other encroachment by a steep, bordering escarpment). Therefore, we also calculated *r* for the area of analysis exclusive of the Nam On watershed —i.e., just the portion of NNT potentially affected by anthropogenic clearing (Table 3).

Table 4 summarizes trends in forest cover derived from the Landsat analysis, and Fig. 8 shows the Landsat classification.

The data sets are consistent in showing a pronounced decline in forest between the 1960s and 1980s, and a subsequent trend of minimal decline or increase in forest cover. It is instructive to consider the trend in forest cover elsewhere in Laos at this time. According to calculations from data in Baker et al. (2000) and Azimi et al. (2001), between 1989 and 1997, forest cover in the whole of Laos declined at an instantaneous rate of 1.7%/year, more than three times the highest rate of decline shown by Landsat for NNT (the period 1976–1989). Before the 1960s, forest cover in NNT must have been very stable—more than 95% of the area remained forested until this time.

On the 1960s maps, 86% of NNT's cleared area is contained within the convex hulls drawn around the forest/non-forest mosaic in the populated stream valleys (Fig. 6). When these 1960s hulls are overlaid onto the 1981 maps, they capture 93% of the 1981 clearing (Fig. 7). Therefore, although deforestation occurred between the two periods, it did so within stable boundaries. It was a process of infilling an existing forest–swidden mosaic, rather than expanding, cancer like, into the dense forests of the reserve.

DISCUSSION

Why did NNT's forest cover begin to decline in the 1970s or early 1980s and, more curiously, why has it stabilized or increased since then, despite increasing population growth of its swidden cultivators? We will start by addressing the first question.

Evidence from interviews, field observations, and written sources show that the decline in forest that began in the 1970s or 1980s was not due to immigration, commercial logging, commercial plantations, or fire. Rather, it was a post-Vietnam War release of agriculture and intrinsic population growth. According to residents of NNT NPA, from the late 1960s to early 1970s, the threat of bombing by American planes prompted many of them to abandon their villages and live in the forest. Consequently, they did much less agriculture than usual and filled the deficit with wild foods. Populations of other villages were relocated outside of NNT by the US-allied Royal Lao Government, and some of these villagers returned to NNT after the war (Chamberlain et al. 1996). Thus, for several years during the war, villagers cleared fewer forest fallows for agriculture than normal, and so rates of forest decline calculated after they returned to their villages in the early 1970s and resumed normal livelihoods would be atypically high. This might account for some of the observed decline in forest cover subsequently. In addition, residents of NNT report that in 1975, when the war ended, cadres of the new communist government visited their villages with upland rice seed, and encouraged them to grow more rice and rely less on wild and cultivated tubers, because the consumption of rice conformed more to the dominant Lao culture (author's own data). It may have also been a well-intentioned attempt to help NNT's villagers recover from the wartime suppression of agriculture. In any case, the consequence was probably clearance of more forest for swiddens than was traditional. The magnitude of this is not known, but villagers in parts of southern Laos report that encouragement by the new government to expand agriculture was the principal driver in loss of natural habitats during the postwar period (I. Baird, pers. comm.).

Given NNT's long human occupancy but low population density (about 1.5 persons/km^2), its high population growth rate must be a relatively recent phenomenon (and is not due to immigration; Alton and Sylavong 1997). Nakai-Nam Theun probably

Table 1. Extent of forest cover and annual rate of change (*r*) in Nakai-Nam Theun National Protected Area from topographic maps covering the full area of analysis, both corrected and uncorrected for scale differences, and the mean of the two results.

	1960s maps		1981 maps		*r* x 100 1960s–1981
	ha	%	ha	%	
Not corrected for scale	300 092	97.3	286 310	92.8	-0.362
Corrected to the 1981 map scale	284 061	92.1	"	"	0.061
Mean	292 077	94.7	"	"	-0.151

followed the general acceleration of population growth in the developing world in the 1960s, from declining mortality due to the spread of medical care (Sinclair and Wells 1989). In NNT, this acceleration would have been delayed by the war, followed by a post-war "baby boom." Additional population was added at this time by the return of some of the villagers who vacated NNT during the war.

What changed in the late 1980s or early 1990s to halt, and perhaps even reverse, the forest loss, despite increasing population growth?

It could be argued that low rates of forest-cover change in NNT are no surprise because it is a protected area. However, the Lao–Swedish Forestry Programme of the Lao Department of Forestry used SPOT satellite imagery to compare forest cover between 1990 and 2000 in three other forested NPAs in central Laos: Nam Kading (NK), Phou Xang He (PXH), and Dong Phou Vieng (DPV). Nam Kading is the nearest protected area north of NNT, and PXH and DPV are the first significantly forested protected areas to the south. Annual, instantaneous rates of forest-cover change for each were -0.49%, -1.2%, and -3.7%, respectively. Combining the three sites yields an annual area-weighted *r* of -1.7%, precisely the same as Laos as a whole in approximately the same period, and a much more negative trend than in NNT. Nam Kading, however, is something of an anomaly in that it is the only uninhabited (or nearly so) NPA in Laos. Excluding it, the annual rate of forest change in the two inhabited NPAs, PXH and DPV, was -3.2%. Although we have no population figures for these areas, their ratios of area to village frame that of NNT: 99 km^2/village in DPV, 66 km^2/village in PXH, and 77 km^2/village in the NNT area of analysis (Division of Forest Resources Conservation (DFRC) 2001). Consequently, differences in population density are unlikely to explain the differences in rates of forest change. In fact, the rate for NNT is much closer to that of the uninhabited NPA, NK, than the inhabited ones.

Sandewall et al. (2001) likewise reported an increase in forest cover in the 1990s at their study site in northern Laos, but attributed it to local declines in human population (-3%/year) from outmigration, a situation not paralleled in NNT.

One factor in the stability of NNT's forest cover is the stability of its villages. Comparison of villages shown on the 1943 topographic maps to those mapped in NNT in 2003 by the Nam Theun 2 WMPA (2004) show precisely 40 named villages mapped by both sources, and 30 of the 1943 villages persisted at more or less the same place and by the same name in 2003 (Fig. 9). Most of the other villages that changed location in some way probably did so as a consequence of the war. Ethnic Sek residents report that some of their villages in NNT have existed at their current locations for almost 300 years (Chamberlain et al. 1996). This is a degree of social stability remarkable for the region. Yet, one of NNT's first management plans called for initiatives to attract "shifting cultivators toward more sedentary livelihoods" (IUCN 1998b:50). This reflects a mistaken notion that "shifting cultivation" equates to shifting populations.

Table 2. Extent of forest cover and annual rate of change (*r*) mapped within the reduced area covered by the 1992–1993 topographic maps, both corrected and uncorrected for scale differences, and the mean of the results.

	1960s maps		1981 maps		*r* x 100, 1960s–1981	1992–1993 maps		*r* x 100, 1981–1993
	ha	%	ha	%		ha	%	
Not corrected to scale	161 462	97.3	151 958	91.6	-0.467	153 954	92.8	0.110
Corrected to the 1981 map scale	155 057	93.4	151 958	91.6	-0.155	151 465	91.3	-0.027
Mean	158 259	95.3	151 958	91.6	-0.311	152 709	92.05	0.042

This social stability explains much of the stability of NNT's forest cover, both pre-1960s and post-1970s. The distance a family can travel from their village to cultivate a swidden is limited by the time and effort of travel (usually by foot) required to reach the site to clear, plant, weed, repel pests (such as birds and wild pigs), harvest, and transport the crop back to the village. If a village doesn't move, the area of its swidden fields cannot expand indefinitely, and few villages in NNT have moved in recent decades.

The stability is probably rooted in an interaction of culture and environment. For example, if Hmong inhabited NNT, it would have seen far more transience in village location and a much larger area affected by swidden cultivation. The Hmong are nomadic, pioneering, shifting cultivators, who periodically move their villages to open up new forest areas for cultivation, often never to return to the former site. Hmong origins are far to the north, in the harsher and more densely populated environment of southern China (they have been moving south into Laos for about 250 years), where more vigorous exploitation of local resources is required, and thus developed. In contrast, the earliest known inhabitants of NNT, who still live there and comprise about 25% of its population, are Vietic-speaking hunter–gatherers/recently emergent agriculturalists. They have diversified into several cultural types depending upon contacts with other cultures. Yet, as a group they retain two things in common: subsistence systems with low impact on the environment, and a propensity for sedentariness (the Vietic groups in NNT have never spread outside the area, and none is further than 1–2 days' walk from the others). For example, they are closely tied to guardian, territorial spirits that inhabit particular geographic sites, e.g., stream valleys (Chamberlain et al. 1996). Vietic people prefer to live in or near such sites so they can make regular offerings of food and other gifts to the spirits, and they suffer significant emotional trauma should something require them to move (Chamberlain 1997; J. R. Chamberlain, unpublished manuscript).

Furthermore, the rich environment, good soils (Anonymous 2008) and low population density of NNT have probably played a role in settlement stability, by providing enough local resources (including forest land for swidden) to support residents indefinitely without moving. Russell (1988) summarized estimates from five tropical areas (India, Borneo, Java, African rainforest, and African savannah woodland) of what he termed "critical population densities of swidden farmers"—human densities within which swidden cultivation is sustainable without altering its traditional practice. His estimates range from 10 to 50 persons/km^2. The convex hulls (Figs. 6–7) that enclose nearly all NNT's villages and the area they use for agriculture total 750 km^2 (about one-fifth of NNT). This equates to a population density of eight persons/km^2 within the area of the hulls, below Russell's lowest sustainability threshold estimate. It is possible then that, despite recent population

Table 3. Values of *r* x 100, exclusive of the uninhabited Nam On river watershed.

	1960s–1981	1981–1992/1993
Full map area, not scale corrected:	-0.490	n/a
Full map area, scale corrected:	0.061	n/a
1992/1993 map area, not scale corrected:	-0.647	0.126
1992/1993 map area, scale corrected:	-0.227	-0.069
Mean	-0.326	0.029

growth, NNT's residents and their traditional livelihoods remain within carrying capacity. Chazee (2000) reached the same conclusion based on his firsthand observations in three NNT villages.

In sum, NNT's residents have little cultural propensity to move their villages, and environmental limitations have not forced them to.

Nonetheless, even if they don't move, as swidden cultivators increase in population, they must find or grow more food. There are four conceivable scenarios under which villages in NNT NPA could feed sharply growing populations while maintaining stable forest cover since the 1980s:

1. increased reliance on wild forest foods;
2. production of a rice surplus (e.g., for export) in the past that now goes toward feeding the additional population;
3. increased food production through agricultural intensification and/or adoption of new agricultural methods; and
4. importation of food from outside the village, by purchase or barter.

We found no evidence for the first two possibilities, and will consider the last two in turn.

Agricultural Intensification

Subsistence societies can sometimes respond to growing populations by intensifying rather than expanding their agriculture, and this has been promoted by the GoL as part of its campaign to control swidden. Chamberlain et al. (1996) reported that at least as early as 1996 villagers in NNT were aware of the GoL's swidden reduction policy, but they had no sense of how well villagers adhered to it. Two lines of evidence suggest that such GoL initiatives alone do not explain the recent stability of forest cover in NNT. First, villages in NNT are, compared with other areas of the country, more isolated from the reach of the GoL administration and monitoring. Only a few villages can be reached by truck (and only in the dry season along one dirt track). If anything, efforts to reduce swidden were probably pursued less intensely in NNT than in other areas of the country. In any case, the topographic map analysis shows that forest loss was already abating in the decade between 1981 and 1992–1993, but implementation of the GoL's campaign to control swidden through land allocation didn't commence until 1995 (MAF 2003).

If villagers took it upon themselves to intensify agriculture, they could do little to increase the annual production of an upland swidden field as the field cannot be irrigated, widely treated with fertilizer application, or easily sprayed against weeds and insect pests. Nor have new, higher-yielding varieties of rice been introduced into NNT to any signficant degree (Anonymous 2008). The only options for intensification are to shift to fixed plots such as rice paddies, or reduce the fallow

Table 4. Forest classified from Landsat (area of analysis = 256 975 ha) and the annual rate of change (*r*) between sample periods.

Year	Forest cover (ha)	Forest cover (%)	*r* since previous sample year (x 100)
1976	234 722	91.3	—
1989	218 995	85.2	-0.533
2001	228 141	88.8	0.341

period between swiddens. The latter, however, reaches a point of diminishing returns in productivity if fallow periods drop below about 5 years (Hansen and Sodarak 1997).

Rice paddies are uncommon in NNT, due to limited level terrain, unsuitable soil, and to some extent, limited cultural experience with or interest in paddy development among NNT's ethnic groups. Nor does the evidence indicate that reduction in fallow periods accounts for stability of forest cover. This is discussed more fully in Appendix 1.

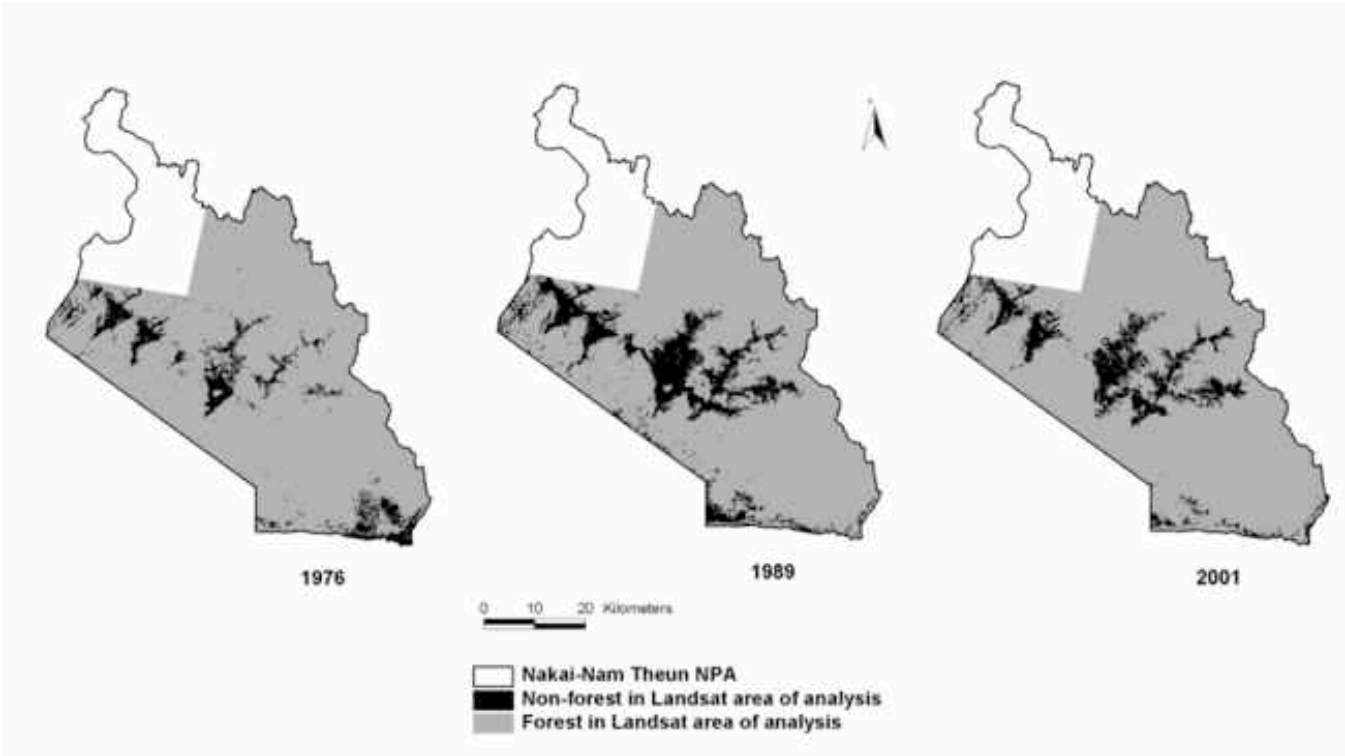
Importation of Food from Outside the Village

Despite the central role of rice in their diet, upland families in Laos rarely produce enough rice to feed themselves for the entire year. But in Laos, and in particular in the rich environment of NNT, rice insufficiency is not the same as food insufficiency (Chazee 2000). Villagers employ various strategies to fill their nutritional needs, including consumption of non-rice crops (e.g., corn, cassava), wild foods, and selling or bartering livestock or labor for rice (Asian Development Bank (ADB) 2001, Dechaineux 2001, Krahn and Johnson 2007). Another important strategy is the collection and sale of wild animals and plants to obtain cash to buy rice (Chamberlain et al. 1996, Foppes 2001, Nooren and Claridge 2001).

Wildlife trade has been particularly important in NNT NPA. In fact, the most prominent economic shift in NNT in the last 20 years has probably been the explosion in wildlife trade, principally to neighboring Vietnam of animals valued in traditional East Asian medicine. In NNT, some animals and plants are harvested directly by transborder Vietnamese poachers, whereas others are collected by local villagers and sold to itinerant Vietnamese traders or Lao middlemen (Fig. 10). Many of the animals are destined for China (Nooren and Claridge 2001), and the broad figures are staggering. For example, each year tens of millions of wild turtles enter China through the trade networks (van Dijk et al. 2000). At least as recently as 2006, up to one metric ton per day of live pangolins (*Manis*) (some probably sourced from other countries) regularly passed from Lao PDR to Vietnam at one border crossing on the northern edge of NNT.

The trade in wildlife and forest products from Nakai-Nam Theun is at least centuries old (Hickey 1982, Tran Van Quy 2002), but the current, catastrophic intensity is a phenomenon of only the past two decades. Local villagers consistently report that Vietnamese poachers and wildlife traders first appeared in NNT in significant numbers in 1984 or 1985 (Robichaud and Stuart 1999). This may have been the consequence of economic liberalization in Vietnam and China, and/or a rapprochement and renewed crossborder trade between the two countries after China's punitive invasion of Vietnam in 1979. In any case, the demand from Vietnamese and ultimately Chinese trade networks for a diversity of wildlife from Laos quickly reached alarming levels (Nooren and Claridge 2001). Figure 11 tracks the escalation in price since 1990 that a Vietnamese trader will pay a Lao villager for a single 1 kg Chinese Three-striped Box Turtle (*Cuora trifasciata*, or "golden turtle"), the single most valuable animal in the region's wildlife trade. Its

Fig. 8. Changes in forest clearance in Nakai-Nam Theun National Protected Area as revealed by supervised Landsat classification.

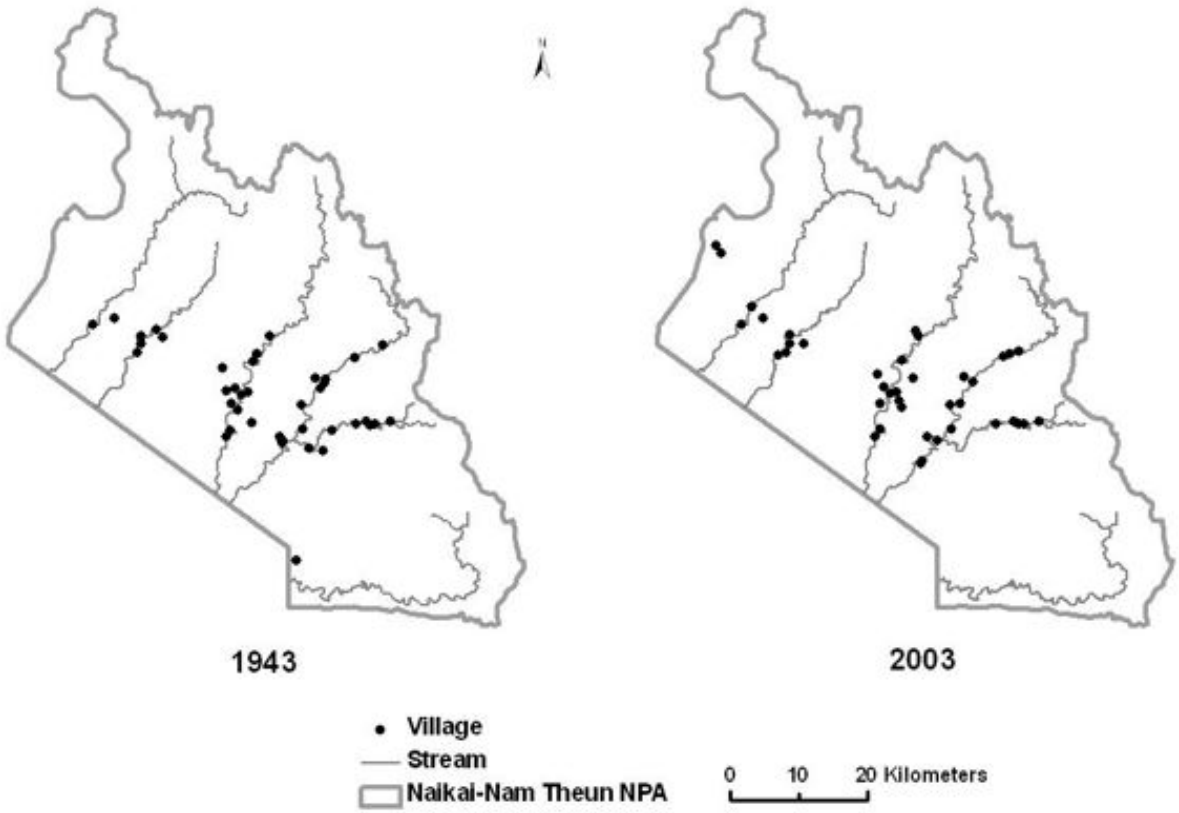


high value comes from the fact that in China its fresh blood is believed to cure cancer (Yoon 1999). Two NNT villages involved in the trade reported that they handled 300 of these turtles per year in the early 1990s, but by the late 1990s the figure had declined to 1–10 year, due to heavy exploitation of the species (Timmins and Khounboline 1999). It is now so rare that in the course of several wildlife surveys in NNT and adjacent areas since 1994 (including three by herpetologists), no biologist has succeeded in seeing a single specimen of this species, wild or captive.

Table 5 shows prices for other wildlife quoted in successive years in the late 1990s in areas in or near NNT, including a proposed extension to the reserve. Recently, trade in wildlife has been supplanted in part by an explosive demand for and illicit trade in rosewood (*Dalbergia*), with local black market prices peaking since 2006 at about U.S.$8000/$m^3$ (P. Panyanouvong, pers. comm.).

It is instructive to place these various prices in two contexts. First, during much of this period, about 75% of the Lao population lived on <$2/day (UNDP 2004b), and the proportion was undoubtedly higher in rural areas. Second, many of the species shown in Table 5 (as well as rosewood) had little or no cash value before 1985. Therefore, subsequent village cash income in NNT must have increased substantially from sales of wildlife and other forest resources, a conclusion with which Chamberlain et al. (1996) and Chazee (2000) concur. An anthropologist who worked in NNT during the period of forest stability wrote of a vehicle track that had been cut into the area several years earlier: “This road has never been a way of communication or transportation for villagers because nobody had [sic] motorbike, car or lorry. This road just provides many facilities for the traders from Laos and Vietnam to buy and carry precious wood....and many non-timber forest products (NTFP) including....protected wildlife” (Culas 2001).

Fig. 9. Locations of villages mapped in 1943 and 2003 within the area of Nakai-Nam Theun National Protected Area.



Foppes (2001), in a survey of the use of non-timber forest products (NTFPs) in three villages in NNT, documented two phenomena: an unusually high use of NTFPs by NNT's residents, and an acute decline in the past decade in several species of commercial value due to a sharp increase in external demand. Items as diverse as large rattans and *C. trifasciata* turtles are now nearly commercially extinct in NNT.

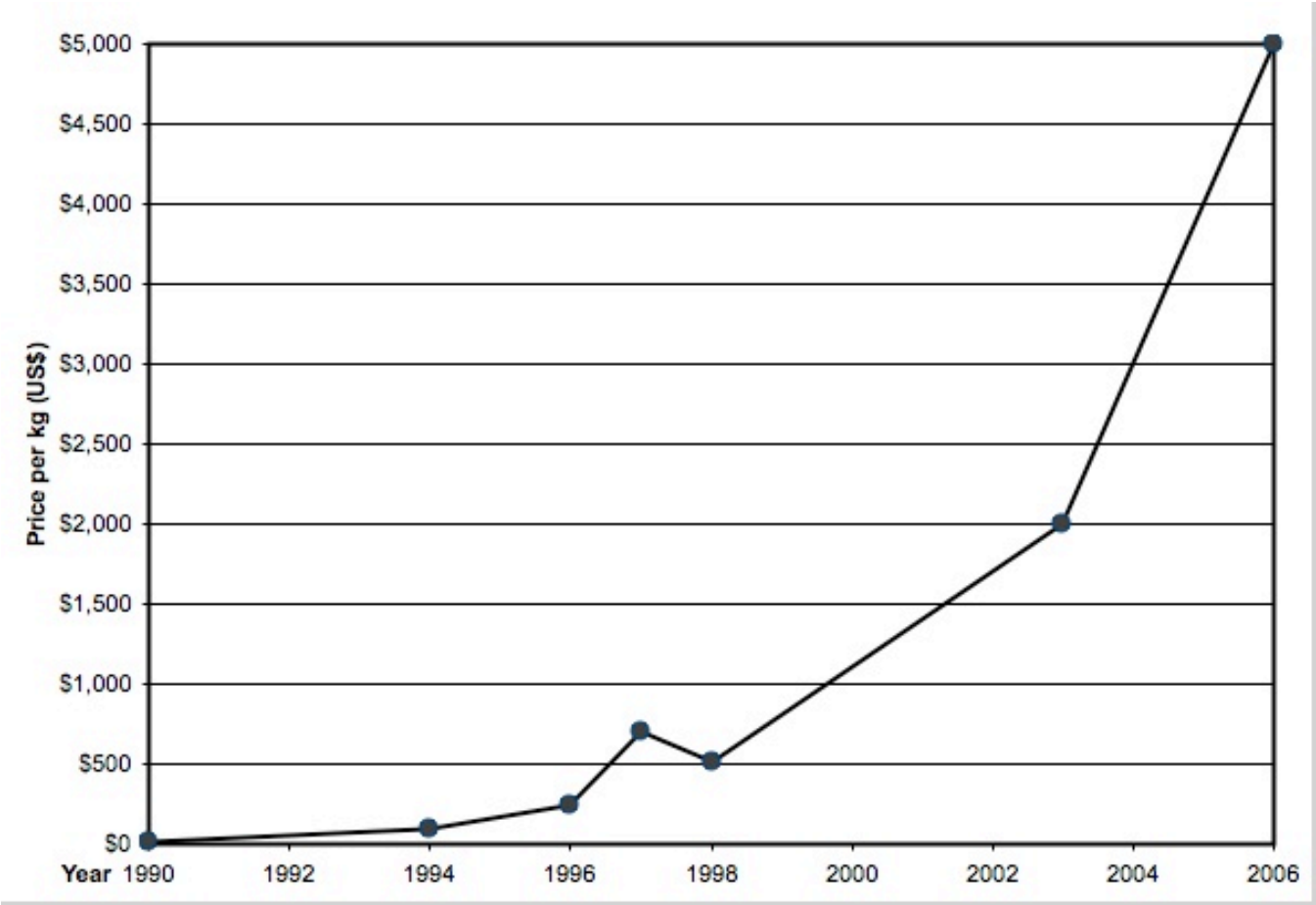
Yet, NNT's residents have no cars, few motor boats, and in fact few tangible possessions of significant value. What then, have they done with the income earned from selling U.S.$5000 turtles? We speculate that income earned from wildlife trade has allowed villagers to buy rice instead of opening new swiddens to grow it, and that this is a major factor in the recent stability of NNT's forest cover. We discuss this in more detail in the next subsection.

Fig. 10. Staff of the NNT NPA's management body, the Nam Theun 2 Watershed Management and Protection Authority, with live turtles and tortoises confiscated from wildlife traders near the protected area (2006).

Speculation

Socioeconomic surveys and interview data are often not helpful in determining the contribution of wildlife trade to household income, since the activity is illegal and thus villagers usually conceal its magnitude from outsiders (WMPA 2005, Singh 2008). Nonetheless, it is widely known that trading or selling wildlife for eventual purchase of rice is a long-standing practice in NNT NPA (WMPA 2005). Several lines of evidence lead us to conclude that it has substituted for clearing new forest swiddens to feed growing village populations. First is the close alignment in timing (1980s to present) between the commencement of intense wildlife trade and the counterintuitive advent of forest cover stability in NNT. Second, in general, maximization of agricultural production is not the goal of traditional forest swiddeners. Instead, their goal is minimization of labor (Beckerman 1983), and this is particularly true of the ethnic groups inhabiting NNT (J. Chamberlain, pers. comm.; V. Phetnavongxay, pers. comm.). That is, work continues until current subsistence needs are met

Fig. 11. Prices in Laos of Chinese three-striped box turtle, *Cuora trifasciata*.



then stops, and collecting and selling a turtle is undoubtedly a quicker and easier way to meet subsistence needs than clearing and cultivating a swidden. In contrast, Hmong would likely do both —sell turtles and continue to open new swiddens to the extent their labor pool allowed.

Third, given NNT's unusually diverse and abundant biodiversity and its proximity to trade networks in Vietnam, its residents have been better positioned to profit from trade in natural resources than villagers in most other areas of Laos, and their embracement of this opportunity was noted by Chazee (2000). This contrasts with the situation in the two protected areas near NNT that have seen significant declines in forest cover, Dong Phou Vieng and Phou Xang He. These sites are naturally poorer in biodiversity than NNT (Robichaud et al. 2001) and, unlike NNT, do not border Vietnam. Consequently, the intensity and value of wildlife trade there has undoubtedly been lower than in NNT.

Finally, and most tellingly, NNT villagers themselves have explicitly noted the link; upon the introduction of the first rice bank in NNT in 2006, in the village of Ban Navang, residents commented that it would reduce their need to sell wildlife to buy supplemental rice (Craig 2006).

Brashares et al. (2004) similarly documented a shift to increased exploitation of wildlife in Ghana in response to declines in Ghana's offshore fishery, a traditional source of income and protein. But the

Table 5. Wildlife sale prices in the vicinity of Nakai-Nam Theun National Protected Area, 1997–2005. Adapted from Robichaud and Stuart (1999); 2003–2005 data from Robichaud (2003, 2005)

	Prices in U.S.$ equivalent	
Species	1998	2003–2005
Big-headed turtle, *Platysternon megacephalum*	$12.00/kg	$15.00/kg
Indochinese box turtle, *Cuora galbinfrons*	$4.00/kg	$3.00/kg
Soft-shelled turtle, *Amyda/Pelochelys*	$6.00/kg	$7.00-10.00/kg
Tokay gecko, *Gecko gecko*	$0.80 each	
Monitor lizards, *Varanus* spp.	$4.00/kg	
Pythons, *Python* spp.	$0.80/kg	
(King?) cobra, *Naja* sp/*Ophiophagus hannah*	$20.00/kg	
Pangolins, *Manis* spp.	$18.00/kg	$20.00/kg
Macaques, *Macaca* spp.	bones: $0.80/kg infants: $6.00/each	
Douc Langur, *Pygathrix nemaeus*	bones: $0.80/kg infants: $24.00/each	
Gibbons, *Nomascus* spp.	bones: $0.80/ kg infants: $40.00/each	
Bears, *Ursus* spp.	gallbladder: $3000.00/kg	
Otters, *Lutra/Aonyx* spp.	$40.00/pelt	$100.00/pelt
Antlers of Sambar, *Rusa unicolor*	$24.00/set	$50.00–300.00/set

shifts differ in nature: resource scarcity made it obligatory for Ghanaians, whereas it has probably been optional for NNT's residents, adopted in the interests of labor minimization. Alternatively, or additionally, it may be a response to pressure from the government to reduce swidden, a phenomenon that Baker et al. (2000) observed in Vietnam: "By prohibiting clearance of fallows for cultivation, the Government forces swiddeners to rely upon NTFP collection, hunting wildlife, fuelwood collection, timber cutting, selling rights to their land, and hiring out their labor to meet their subsistence needs."

In sum, villagers in NNT continue to rely on the forest as their populations increase, but have partially shifted their pattern of use from growing rice in expanded forest swiddens to buying rice from the sale of wildlife.

CONCLUSIONS

After a long period of stability, external drivers precipitated a sharp increase in forest loss in NNT NPA about 30 years ago. This trend shift has since been ameliorated by a combination of both intrinsic

factors (sedentary cultures which are not resource maximizers), and an extrinsic one (foreign demand for wildlife valued in traditional East Asian medicine).

The situation is neither stable nor sustainable, as the resources valued in trade are not harvested sustainably. The trade "bounty" is temporary, and depletion of several species has already occurred and more will likely follow without strong intervention.

The situation presents a conundrum for the management of NNT. Attempts to suppress natural resources trade could promote increased forest loss from swidden, and vice versa. Simultaneous suppression of both swidden and trade would probably, in at least the near and mid-term, reduce villagers' livelihood security and standard of living (which is already at a very basic level). Simply opening access to markets for legitimate village cash crops is probably not an answer. The area is so remote that developing the substantial access required to make cash cropping economically viable risks sharply exacerbating the illicit removal of natural resources from the reserve (control of this is already one of the biggest challenges for NNT's management, at the current low level of access).

Our findings point to the following observations and recommendations for NNT's management authorities, which may offer at least partial solutions to sustainability of both livelihoods and biodiversity in NNT:

1. Illegal trade in wildlife and other forest resources is a greater immediate threat to the biodiversity values of NNT than local swidden agriculture, and this is where management attention should focus first. Put simply, there is far more forest left in NNT than wildlife, fish, and NTFPs.

2. While working to control wildlife trade, seek local solutions to develop alternative sources of food and income (e.g., improved livestock production, improved productivity of existing rotational swidden systems, development of paddy where possible) before also reducing access to swidden land. Successful alternatives to swidden must be in place before simultaneously restricting both foundations of current village subsistence, lest local livelihoods suffer and the ensuing scarcity push people back into the resources trade.

3. Because the factors that accelerated forest loss in NNT (post-war baby boom and promotion of agricultural expansion) are not endemic characteristics of the local human–forest ecology, traditional village livelihoods should be approached as potential solutions to environmental sustainability, rather than as problems to be fixed or discarded. At a minimum, a better understanding of the swidden systems in NNT should be achieved before introducing external controls on their practice.

4. Finally, to conserve both forest cover and villagers' welfare in NNT, it is more important to focus on alleviating population growth than controlling swidden. Russell (1988) observed of swidden: "....this farming system is superbly well adapted for conserving tropical forest, *unless* the local population exceeds a critical density." He concluded that unless human population growth is addressed, "....all other conservation measures are futile, always in the long run and often in the short run." Indeed, the main cause of increased forest loss in NNT after the 1970s was not a fundamental change in local agricultural systems, but a precipitous change in human population, and consequently that is where long-term solutions are best sought.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol14/iss1/art33/responses/

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Appendix 1. Relationship between forest stability and fallow period.

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