Shifting Cultivation: A New Old Paradigm for Managing Tropical Forests

BY JEFFERSON FOX, DAO MINH TRUONG, A. TERRY RAMBO, NGHIEM PHUONG TUYEN, LE TRONG CUC, AND STEPHEN LEISZ

Shifting cultivation, or swidden farming, is often held to be the principle driving force for deforestation in tropical Asia (Myers 1993). National governments in Southeast Asia, notably in Indonesia, the Philippines, Thailand, and Vietnam, have been inclined to blame shifting cultivators, usually members of ethnic minorities, for rapid loss of forests (Dove 1984, Do Van Sam 1994, Le Trong Cuc 1996, Rambo 1996). In Vietnam, the official view of shifting cultivation has been particularly negative, reflecting a combination of the ethnocentric assumptions of the numerically dominant Kinh (lowland Vietnamese) about the cultural superiority of wet rice farming and the Marxist view that swiddening represents a primitive stage in the cultural evolutionary sequence (Jamieson 1991, Rambo 1995).

Resource managers in these countries invariably see shifting cultivation as a single, simple system of farming in which the forest or scrub is slashed and burned to make swiddens. These fields are cultivated for only one or two seasons before soil fertility is exhausted or weed growth overwhelms the crops (Padoch et al. 1998). The field is then abandoned and the farmers move on to clear a new field elsewhere in the forest. From this perspective, swidden farmers are "forest eaters" whose unending search for new forests to clear is a major cause of deforestation. However, to view swiddens as just temporary fields surrounded by abandoned land under wild growth is wrong. More than four decades ago, Harold Conklin (1957) pointed out that "shifting cultivation may refer to any one of an undetermined number of agricultural systems" (p. 1). Spencer (1966) described 18 distinct types of shifting agriculture within Southeast Asia alone. Brookfield and Padoch (1994) argued that swidden agriculture is not one system but many hundreds or thousands of systems.

This article seeks to describe the agroecosystems of a hamlet in northern Vietnam in which traditional shifting cultivation has not resulted in extensive deforestation, but it has altered the character of the vegetative cover. Through analyses of this agroecosystem, we seek to develop a better understanding of the swidden agricultural systems found in the region and the effects of these systems on land-cover change in the area over the last 40 years. Our findings have implications for understanding the role of shifting cultivation at more macro levels, including its contribution to global climate change.

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Figure 1. The composite swidden system in the dry season. Paddy fields are in the foreground, with recently cleared/burned swidden fields in the background surrounded by secondary vegetation.

Shifting cultivation, the subject of this article, differs from the common practice of using fire simply to clear forests for permanent cultivation, pasture, or further development. The latter practice was employed on a massive scale during the European settlement of the frontiers of the eastern United States (Rambo 1990). This slash-and-burn cultivation, as practiced by the millions of lowland Vietnamese resettled in upland areas since the 1960s, turned large areas into virtual lunar landscapes (Le Trong Cuc et al. 1990).Of course, some traditional forms of shifting cultivation can also cause long-term environmental degradation."Pioneer" shifting cultivation, for example, is a system in which new areas of forest are cleared for fields,allowed to remain under cultivation too long, and then abandoned in a degraded condition (Kunstadter et al. 1978). In northern Vietnam, Hmong farmers have converted large areas in the highlands to grasslands as a result of pioneer swiddening.

Nevertheless, in focusing on destructive forms of slash-and-burn cultivation, national governments and resource

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managers have ignored the nature of more common and more sustainable forms of swidden cultivation. Alcorn (1990) calls swidden farming "managed deforestation," a system built around patchy, pulsed removal of trees but not of the forest. She suggests that indigenous farmers work to manage deforestation in sequential agroforestry systems that integrate secondary successional vegetation—everything from grass and bushes to young open-canopy tree communities to mature closed-canopy tree communities. Brookfield and Padoch (1994) suggest that the concept of abandoned fallows is being displaced by research that shows that the plants found in any stage of secondary successional vegetation are in large measure the result of conscious planning. Even where the forest that succeeds farming is not closely managed, it is used. (The "fallow" is the period when land is left to recuperate and vegetation allowed to regenerate. It is not "abandoned" land, which the swidden farmer does not intend to use again. Rather, it is part of the land-use system in which the farmer will return to this plot again. Meanwhile, while it lies fallow, the farmer may use it to collect numerous food, timber, and nontimber forest products. Popular conception, however, is to view this land as "abandoned fallow.")

Failure to understand the swidden agricultural system, and its associated secondary vegetation, has led scientists to overestimate the amount of "deforestation" that has occurred in Southeast Asia. Potter et al. (1994) suggest that as much as 26% of all land in Southeast Asia falls into the "other" category, which includes scrub, brush, pasture, waste, and other land-use categories that often represent not deforestation but forest fallow or secondary regeneration. Likewise, Kummer and Turner (1994) suggest that approximately 33% of the land cover in the Philippines falls into the "other" category, and this category grew by more than 20,000 ha between 1948 and 1987. In Thailand, the field plan of the Tropics Program of the GEWEX Asian Monsoon Experiment (GAME-Tropics) is based on a land-use breakdown in which fully 49% of the nonforested land in northern Thailand is "unclassified"(GAME-Tropics 1996).

Because swidden agricultural systems are so little understood, many governments have implemented (mostly unsuccessful) large-scale resettlement programs that are intended to convert swidden cultivators into farmers of permanent agricultural fields. Moreover, failure to understand the role played by secondary successional vegetation in swidden systems has meant that resource managers have not correctly identified the impacts, both positive and negative, of swidden agriculture on species diversity, watershed hydrology, and carbon sequestration (Skole et al. 1998), all of which have important implications for biodiversity conservation and global warming.

Shifting cultivation in northern Vietnam

Shifting cultivation has been practiced for centuries,if not millennia, in the northwestern highlands of Vietnam. Yet, contrary to the popular conception that shifting cultivation always causes deforestation,the area under forest cover in many parts of this region has not changed significantly, despite rapid population growth, over the past 50 years. Indeed, a recent study of the Da River watershed (Nguyen Duy Khiem and Van Der Poel 1993) found no correlation between the occurrence of shifting cultivation and the extent of deforestation. In those districts having the greatest extent of swiddening (12–36% of total area), the percentage of land under forest cover ranged from 6% to 48%, whereas in those districts having almost no shifting cultivation (less than 6% of total area), forest cover ranged from 8% to 48%.

Tat, one of 10 hamlets in Tan Minh village (Da Bac district, Hoa Binh province) is representative of many swiddening villages in Southeast Asia. The hamlet is positioned alongside the Muong River, a tributary of the Da River, at an altitude of approximately 360 m above sea level. The Muong valley ranges from a few hundred meters to approximately 2 km wide and is surrounded by peaks reaching from 800 m to over 1100 m. The valley walls are extremely steep, with slopes often exceeding 60% crisscrossed by many small streams flowing into the Muong River. The valley is shaped like an amphitheater, with buttress-forming ridges extending up to the surrounding peaks.

Our understanding of the hamlet's ecosystem is based on an integrated spatial database that incorporated topographic maps, aerial photographs, satellite images, and a digital elevation model with information on elevation, slope, and aspect. Information on land-use practices collected through interviews with farmers and other key informants was georeferenced to the spatial database. This database served as a framework for analyzing changes in land cover and forest patterns through time and as a tool for analyzing the information and insights collected in semistructured informal interviews.

The spatial database was developed on the basis of aerial photographs (nominally 1:40,000) taken in 1952 by the French military, as well as a 1995 Landsat Thematic Mapper image. The aerial photographs were taken as part of a comprehensive mapping of Vietnam.[1] The photographs were manually interpreted and classified into three land-cover categories—secondary regeneration, swidden, and paddy. The secondary regeneration or successional vegetation category was further subdivided into three classes: closed-canopy forest (closed-canopy forest mapped from the 1952 aerial photographs may or may not have been primary forest, but for our purposes we are classifying these forests as secondary vegetation); open-canopy forest; and grass, bamboo, and scrub. These photographs were

[1]We are grateful to Dr. Jean-Francois Dupon,senior scientist of ORSTOM (Office de la recherche scientifique et technique outre-mer), for assistance in obtaining access to these photographs. We would also like to acknowledge the staff of the Institut Geographique National for their prompt and courteous response to our request for the photographs of Ban Tat.

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registered on a map base, and the land-cover categories were digitized and entered into a geographical information systems (GIS) database (Arc/Info software on a Sun Sparc workstation). The Landsat image was classified into the same land-cover categories. Ground-truth points were collected in the field using differential GPS (global positioning system). The Landsat image was registered to the same map base as the 1952 photographs. Spectral signatures of the different land-cover types were derived from a subset of the ground-truth points that were then overlain on the imagery. A supervised classification of the image was done using a maximum-likelihood rule (ERDAS Imagine software). An accuracy assessment of the 1995 satellite-derived land-cover classification showed 95% of the 155 checkpoints correctly classified after accounting for GPS surveying and image registration error.

The socioeconomic database was developed through interviews with many Tay residents of Tat hamlet and provincial, district, village, and hamlet government officials. Researchers documented changes in national and regional policies influencing land use (e.g., tenure, taxation, credit, import and export regulations) as well as changes in infrastructure (roads and markets). We interviewed residents of the village to learn more about the socioeconomic factors contributing to their decision to create or maintain forest fragments in their area. Key informants were used to assess,among other factors, local peoples' perception of the forest. Researchers conducted semistructured informal interviews with villagers to identify the socioeconomic and institutional factors influencing use and management decisions regarding forestland and forest vegetation.

The people of Ban (hamlet) Tat are mostly members of the Tay ethnic minority.[2] They speak a language belonging to the T'ai family. Local oral history maintains that migrants from Son La settled the hamlet a little over 100 years ago. Mobility appears to have been relatively high, with several waves of immigration and emigration.A large group of people migrated from Ban Tat to Nghia Lo, just across the hamlet's northern boundary in Phu Tho province, and kinship ties are still maintained today between these two hamlets.

According to one elderly informant, only seven households, or approximately 50 people, lived in the village in 1954. Today the hamlet has grown to 69 households with a population of 389 people. This represents a population growth rate of roughly 4.9% annually—probably the result of a natural growth rate of 3–3.5% and in-migration. During this period, population density grew from approximately 10 people to 75 people per km^2, which is approximately twice the average population density for the Da River watershed.

For as far back as any informant can remember, the Tay of Tat hamlet have been "composite swiddeners" (Rambo 1996), that is, households simultaneously manage permanent wet rice fields in the valley bottoms and shifting swidden fields on the hillslopes, and they exploit wild resources of the forest. Swiddening as practiced by the Tay is an integral component of the total agricultural system, not an adaptation of an earlier, more primitive,pure swiddening that is in the process of being replaced by more advanced irrigated farming. Neither is swiddening a recent response to rapid population growth that has exceeded the carrying capacity of the wet rice fields and forced people to expand their farming onto the forested slopes. Instead, composite swiddeners such as the Tay have practiced both wet rice farming and swidden agriculture together as an integrated system of subsistence for generations and probably centuries. Figure 1 is a typical landscape in Ban Tat at the end of the dry season. Recently planted paddy fields are seen in the foreground, with newly cleared swidden fields in the background surrounded by secondary vegetation. Similar composite systems are found among the Shan of Burma and northern Thailand (Schmidt-Vogt 1998), the Hani of Xishuangbanna prefecture in southwestern China (Pei Shengji 1985),and the Ifugao of the Cordillera in the Philippines (Dove 1983).

In the case of Ban Tat, elderly informants reported that their parents had told them that they had employed both systems when they first began to settle the valley at least 100 years ago. At that time, the entire area was covered by closed-canopy forest and there was no scarcity of land on which to make paddy fields in the valley bottoms. The area of paddy fields was much smaller than it is now, and good forestland was abundant and free for the taking. It would thus have been possible for households to have had only cultivated paddy fields or only cleared swiddens, but none are reported to have done so. Evidently, there are survival advantages in maintaining a more diversified agroecosystem.

Indeed, the household resource system of the Tay is notable for its incorporation of a wide range of subsystems. A typical Tay household manages a complex agroecosystem. The landscape of Ban Tat is therefore a mosaic of cultivated and fallowed fields interspersed with forest areas protected by the community. Figure 2 shows the fragmented mosaic of swidden fields, secondary vegetation, and older tree cover that compose the Ban Tat landscape. There does not seem to be any regular pattern to this mosaic. Swidden fields can be found anywhere on the slope from the bottom of the hill to the top. A village people's committee that is responsible for allocating land and enforcing regulations regarding forest use administers the hamlet. This committee allocates land to villagers from the two large areas near Ban Tat where swiddening is permitted—Suoi Co San and Suoi Muong. In principle, villagers should alternate their swidden fields between the two

[2]Although officially classified as Tay, the people of Ban Tat are culturally quite distinctive. Some Vietnamese ethnologists argue that they are actually a branch of the White Thai. They are more likely simply a unique local population, one of many variant groups that have evolved under conditions of relative isolation in the northwestern mountains.

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Figure 2. The landscape of Ban Tat in the wet season showing the fragmented mosaic of swidden fields, secondary vegetation, and older tree cover.

areas every several years, leaving one of the areas to fallow and regenerate. In practice, however, because land is scarce, both parcels are used at the same time.

Within the allocated fields (not more than 2 ha per household), the villagers manage their own patterns of rotation between cultivated crops and fallow periods. At clearing time, everyone in the hamlet travels together to the designated forests to mark their fields under the observation of the village people's committee staff. The use of a field, however, establishes no long-term ownership or use rights over that field,and after one cycle of cultivation it is not necessary to return to the same field.

On plots relatively close to the settlement, when the soil is sufficiently fertile the most common current pattern of swidden cultivation is 3 years of dryland rice and 2 years of cassava, followed by 3–4 years of fallow. The length of the fallow appears to be determined primarily by the need for land, and hence smaller households can afford to maintain a longer fallow. The fallow period has been declining rapidly in recent years, reflecting the scarcity of land available for swiddening caused by increased population density and by government intervention to protect the forests.

Home and tree gardens and livestock are also important components of the agricultural system. Home gardens located near people's houses are used to grow vegetables, fruits, herbs, and ornamental plants for household use. More fruit trees, such as plum and apricot, have been planted to take advantage of recent market opportunities. Tree gardens are located upslope from the home gardens in areas used also for cassava swiddens. Trees are grown for local construction needs and for sale as timber and pulpwood. Cattle and buffalo graze in harvested paddy fields, roadsides, and fallowed swiddens and secondary forest areas. Cattle also facilitate material and nutrient flows between components of the agroecosystem (Rambo and Le Trong Cuc 1997). Thus, the generalized spatial pattern of land use is settlement and wet rice fields located at the bottom of the valley, home gardens on the hillside above the houses, tree gardens and cassava swiddens farther up the slope, dryland rice swiddens on the upper slopes, and secondary forest on the crests.

Forests, which are officially managed by the forestry department, can be found across the landscape as well as beyond the home and tree gardens. The district forestry department defines three types of protected forests: primary forests (either primary or well-developed secondary forests), regenerating secondary forests, and watershed forests. Under a national program, the government pays households to protect regenerating secondary forest plots assigned to their care. Forests and scrub not classified in one of these categories can be cleared for swiddens. The fine for cutting protected forest is 800 dong (US$0.08 in 1995) per square meter; however, the chances of being caught are relatively low and the potential gains high, so the fine system is not an effective deterrent to forest clearing in the more inaccessible areas where government surveillance is weak.

Some protected forests are located on the top part of the hills, some are found on the lower part of the hills above the houses with swidden fields on the top, and some are found on the middle of the hills with swidden fields on both sides. Protected forests are also found in gullies running down the slope. These gullies are under the control of the hamlet cooperative and swidden is not allowed. In some areas,particularly on slopes immediately above their houses,farmers themselves preserve the forest to maintain water supply for home consumption.

Deforestation or forest degradation?

The Food and Agriculture Organization of the United Nations (FAO) defines deforestation as "the transfer of forest land to non-forest uses and includes all land where the forest cover has been stripped and the land converted to such uses as permanent cultivation,shifting cultivation, human settlements, mining, and building of dams" (Rao 1989, p. 6). Degradation, on the other hand, "refers to a reduction in the extent and quality of the forest cover due to such factors as indiscriminate logging, inappropriate road-making methods, and forest fires" (Rao 1989, p. 6). Note that FAO defines deforestation as both a change in land cover (i.e., loss of forest cover) and a change in land use (i.e., converted to other permanent uses). Forest degradation, on the other hand, is simply a change in the quality of forest cover.

Other researchers have noted that estimated rates of tropical deforestation vary for several reasons, including ambiguities surrounding the future of forests that have been cut down (Williams 1990, Myers 1991). If a substantial portion of cut forests is regenerating, the rate of deforestation is overestimated in the calculation of the net rate of change in forested areas (Uhl et al. 1988, Turner et al. 1993, Moran et al. 1994). In other words, if the cut forest

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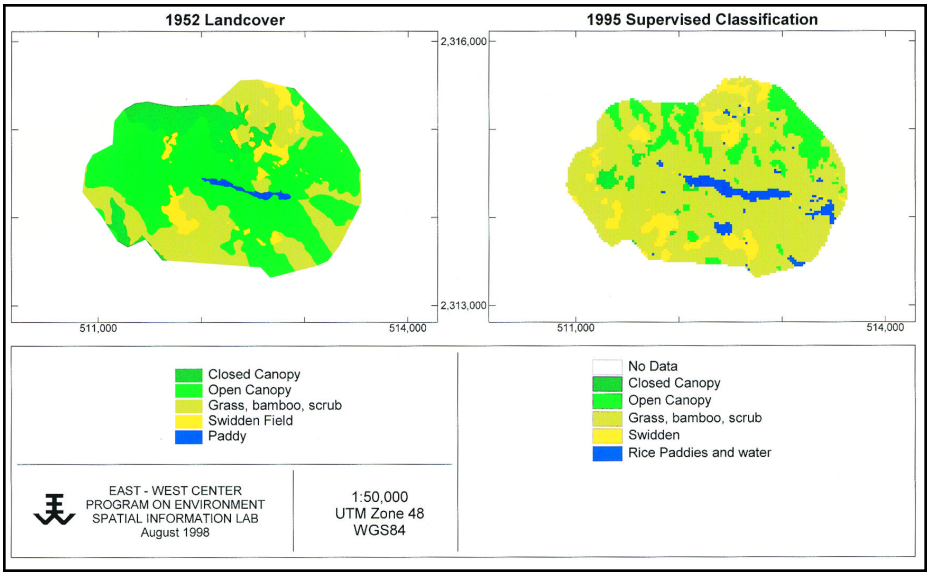

Figure 3. Land cover and fragmentation in Ban Tat in 1952 and in 1995. The Ban Tat land-cover classification map is in Universal Transverse Mercator (UTM) coordinates.

regenerates, the process should be called forest degradation, not deforestation.

Historical changes in land cover and fragmentation in Ban Tat between 1952 and 1995 are shown in Figure 3 and summarized in Table 1. During this period,the area covered by secondary regeneration or successional vegetation decreased from 92% to 84% of the landscape. The area covered by closed- and open-canopy forests decreased from 11% to 3% and 54% to 15% of the landscape, respectively, while the area covered by grass, bamboo, and scrub increased from 27% to 66% of the landscape.

Our finding that 84% of the landscape of Tat hamlet remained under secondary vegetation—despite more than a century of shifting cultivation—shows that traditional swiddening does not necessarily entail permanent conversion but only temporary use of forestland. Hence, we do not describe the secondary regeneration that occurs after shifting cultivation as deforestation. We found only 5% deforestation (the increase in land used for paddies from 1% to 6%) for the study area over the 43 years between 1952 and 1995. Although the amount of land under secondary regeneration remained relatively constant over the 43-year period, closed- and open-canopy forests have degraded to earlier stages of succession. What Ban Tat evidences, as do many swidden agricultural landscapes in Southeast Asia, is not so much deforestation as a change from a fairly homogeneous forest cover (closed and open canopy) to a highly heterogeneous cover of secondary vegetation.

Our work suggests that the other major land-cover change resulting from the long-term practice or tradition of shifting cultivation is a great increase in the degree of forest fragmentation. Significant changes have also occurred in the spatial distribution of that land cover. Between 1952 and 1995, the number of secondary regeneration fragments grew from 18 to 292, and the mean size decreased from 37 ha to 2 ha (Table 1). Fox et al. (1995) found similar results in northern Thailand. The phenomenon of forest fragmentation is well illustrated also in the literature on South America (e.g., Nepstad et al. 1991, McClanahan and Wolfe 1993,Enoksson et al. 1995,Schelhas and Greenberg 1996).

Scientists have only recently begun to study the effects of fragmentation on biodiversity in general, on species composition of forest ecosystems, and on forest hydrology. Field surveys in Southeast Asia have shown that the diversity of species in forest fragments is often comparable with that in more mature forests (see Xu et. al. 1993, Schmidt-Vogt 1998). Studies in Kalimantan, Indonesia (Padoch and Peters 1992, Lawrence et al. 1998), showed that although diversity of both plants and birds is lower in swidden areas than in the primary forest, some sites have 50–80% of the diversity of comparable natural forests. Large wild mammals (e.g., rhinoceros, tiger, elephant) are more adversely affected by forest fragmentation, however. The decline in other, more adaptable mammals (e.g., wild pig, deer) at Ban Tat is probably more the result of overhunting than it is a consequence of habitat fragmentation.

The hydrological effects of forest fragmentation depend on the size and degree of fragmentation. Discontinuity in land-surface properties across a forest edge gives rise to microclimatic effects extending toward the interior of a forest fragment (Collins and Pickett 1987, Murcia 1995). Furthermore, the spatial heterogeneity of land-surface characteristics resulting from forest fragmentation can induce changes in mesoscale circulation, convection, cloudcover, and rainfall (Yan and Anthes 1987, Giorgi 1989, Henderson-Sellers et al. 1993).

Social, economic, and cultural factors play important roles in both the creation and maintenance of forest fragments (Schelhas and Greenberg 1996). Although the causal associations between such factors and the creation and maintenance of forest fragments are not clearly understood, social forces appear to exist that promote the maintenance of a patchy landscape even when many rural inhabitants have modified traditional agricultural systems, increased yields, supplemented incomes with earnings from off-farm employment, or migrated to urban areas in search of wage-paying jobs.

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Table 1. Land cover and fragmentation in Ban Tat in 1952 and 1995.[a]

	1952		1995		1952		1995	
Land Cover	Ha	%	Ha	%	Number of fragments	Mean size (ha)	Number of fragments	Mean size (ha)
Secondary regeneration	681	92	616	84	18	37	292	2
Closed canopy	81	11	19	3	4	20	19	1
Open canopy	400	54	110	15	5	78	40	3
Grass,bamboo,scrub	200	27	487	66	9	22	233	2
Swidden	52	7	73	10	35	1	75	1
Paddy	7	1	43	6	1	8	45	1
Total	740	100	732	100	54	13	412	2

[a]When we superimposed the Landsat image on the aerial photographs,Landsat pixels (picture elements or grids) at the edge of the image did not align perfectly with the aerial photographs and were eliminated. This explains why the total area is slightly different for the two dates.

Changes in land use and land cover in Ban Tat are at variance with the conventional wisdom that shifting cultivation,under conditions of increasing population density, inevitably results in extensive deforestation. Part of the variance is attributable to how we define deforestation as opposed to forest degradation, but two other factors are equally, if not more, important. First, and perhaps most significant, is the high sustainability of the composite swiddening system employed by the Tay, which outside observers have not previously appreciated. Because paddy production can be intensified as population density increases, combining paddy fields with swiddens in a single subsistence system relieves some of the pressure to clear more forest. Households in Tat hamlet derive approximately half of their carbohydrate supply from their paddy fields, even though these fields are much smaller in area than the swiddens. The second factor, also related to the Tay land-management system, is the importance of secondary regrowth and the Tay's active efforts to maintain a mosaic of land cover across the full spectrum of the various stages of forest regrowth. This complex, indigenous land-use system thus both maximizes the stability of food production and the percentage of the landscape dominated by secondary vegetation.

Our work leads us to question whether too much emphasis has been placed on the effect swiddening has had on land cover (changes from homogeneous forest to highly heterogeneous cover of secondary vegetation) and too little emphasis on the stability of swidden agriculture as the main land-use system in this region. In other words, what would happen if deforestation—and not just forest degradation—finally occurred? Permanent agriculture could result in land cover dominated by trees (e.g., rubber, palm oil,cardamom, or tea) or in one composed of annuals (e.g., maize, cassava, and upland rice). Current trends toward tree gardens indicate that the hamlet may be able to maintain a high percentage of tree cover. In either the tree-dominated or annual-crop scenario, however, biodiversity, as measured by the number of species found on the landscape, would decline (Lawrence et al. 1998). Hydrological impacts could be considerably more severe than those experienced under secondary vegetation of the traditional swidden system (Zinke et al. 1978, Alford 1992, Forsyth 1994). Carbon sequestration might be approximately the same under an intensive tree-crop system as it is under swiddening, but it would be negligible under an annuals system (Tomich et al. 1998). The short-term economic returns of converting from secondary vegetation to a market crop, however, would probably be higher than under the swidden system; indeed, the worldwide trend toward a global economy might very well drive a move from swidden to permanent agriculture over the next few decades.

Tat hamlet has been fortunate in being able to survive the changes of the last several decades with minor variations in the total area covered by secondary vegetation (see Table 1). Government officials and planners need to recognize that perhaps the biggest effect of tropical forest degradation has been a change from a relatively homogeneous forest to a highly heterogeneous and fragmented cover of secondary vegetation. The land cover may be degraded in terms of merchantable timber species. However, this secondary "degraded" vegetation, a product of the swidden land-use system, might well be the most species rich and water- and soil-holding land cover available. In addition, composite swiddening is the land-use system most suitable for meeting the needs of the local community.

A new old paradigm for managing tropical forests

Chazdon (1998) suggests that tropical biodiversity conservation is undergoing a conceptual transition in which isolated forest fragments, logged forests, and secondary growth forests are now being recognized for their value in the conservation of biological diversity. These studies reinforce a new paradigm in the management of tropical biodiversity that extends conservation to human-impacted

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lands (Pimentel et. al.1992, Janzen 1998).

Failure to see the benefits as well as the costs of secondary vegetation and the swidden agricultural system has led to government policies for settling swidden farmers—many of which have been failures.A more efficient,as well as humane, policy would be to invest in research on methods of maintaining the biodiversity associated with swidden fallows while increasing their productivity and soil-sustaining properties. Failure to understand secondary successional vegetation has also meant that resource managers have often failed to recognize the implications, both positive and negative, of swidden agriculture on biodiversity, watershed hydrology, and carbon sequestration (Skole et al. 1998).Finally, models of global climatic change have been based on an extreme scenario of forest conversion to degraded pasture or impoverished grassland (Giambelluca 1996). Failure to account for the effects of landscape heterogeneity may mean that significant effects of land-cover change are not being recognized.

Swidden cultivation is an old paradigm built around the temporary removal of trees but not of the forest. As we enter the new millennium, we would do well to recognize the power of this paradigm for managing tropical forest ecosystems.

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