THE END OF SWIDDEN IN BHUTAN
Implications for forest cover and biodiversity

Stephen Siebert, Jill Belsky, Sangay Wangchuk, James Riddering

Introduction

Bhutan and the eastern Himalayas more generally are among the world’s most biologically and culturally diverse areas; home to numerous cultures with long and rich traditions of forest use and management. This paper explores relationships between swidden and ecological disturbance regimes, forest cover and biological diversity in Bhutan. Specifically, we consider the role and importance of swidden on forest cover, flora and fauna, since it can be thought of ecologically as a historic anthropogenic disturbance. Further, we reflect on the potential implications associated with the end of historic swidden practices as an ecological disturbance.

For a small country of just 38,000km², Bhutan contains extraordinary biological diversity. It is home to at least 5,500 plant species, more than 160 mammal species and 616 bird species (Inskipp et al, 1999; Groombridge and Jenkins, 2002). This includes a number of charismatic vertebrates of international conservation interest, including tigers (Panthera tigris), which are considered an umbrella species for the conservation of other biodiversity (Wikramanayake et al., 2011). In an influential publication, WWF (2005) documented the global biodiversity conservation significance of Bhutan and the eastern Himalayas, and offered several explanations for the region’s importance, including: 1) its location in the convergence zone of two biogeographic realms (the Palearctic and Indo-Malayan), 2) climatic variability associated with tremendous topographic relief, 3) complex and steep topography, particularly along...
a north-south axis, and 4) the isolation of plant and animal populations due to topography and climate. While this explanation encompasses important continental and regional environmental influences on biodiversity, it ignores the importance of iterative local biological and anthropogenic forces, including swidden. This paper documents recent changes in the area under swidden cultivation and forest cover, offers reasons for the continued demise of swidden, identifies and describes disturbance attributes associated with historic swidden practices, and evaluates potential effects that changes in swidden and associated disturbance regimes may have on biological diversity (i.e., flora and fauna).

Biological diversity and the structure and function of ecosystems reflect site-specific ecological-disturbance regimes (Mori, 2011; Uhl et al., 1990). Disturbance is defined as “discrete events in time that disrupt the ecosystem, community, or population structure and bring about a change in resources, substrate availability, or the physical environment” (Mori, 2011). Both natural and anthropogenic disturbances create these effects, and consequently both warrant attention.

Ecologists have attempted to characterize disturbance attributes for decades. In a comparison of natural and anthropogenic disturbances in the Amazon, Uhl et al. (1990) employed the type, size, duration and frequency or return interval of disturbances as a means of comparing their differing ecological effects. More recently, Mori (2011) argued that disturbances could be characterized by their type (e.g., tree fall or swidden), spatial characteristics (i.e., the area, shape and spatial distribution of patches created), temporal characteristics (i.e., the frequency, return interval, cycle and rotation period), specificity (i.e., relationships between types of disturbances and the characteristics of the disturbed site, such as species, size class and seral stage), magnitude (i.e., disturbance intensity and severity) and synergisms (i.e., interactions among different kinds of disturbances over time).

One challenge in describing historic disturbance regimes, whether natural or anthropogenic, is that they are constantly changing in unpredictable ways in response to normal variations in climatic conditions, random (i.e., stochastic) events, and other factors which affect subsequent disturbance impacts and trajectories. Nevertheless, by identifying and characterizing specific attributes of historic disturbance regimes, the influence they may have exerted on the composition, structure and distribution of flora and fauna can be evaluated.

Important natural ecological disturbances in Bhutan include: 1) landslides and other erosion/mass wasting processes characteristic of young, steep mountain topography in conjunction with heavy monsoonal rainfall and 2) tree-fall gaps associated with wind, insect- and disease-induced mortality. Landslides and tree falls, while very different in terms of specific disturbance attributes and effect, both create gaps in forest cover and favour the establishment of light-demanding, early successional plant species and associated fauna. The creation of gaps in forest canopies play a major role in the maintenance of woody species diversity in tropical and other forest ecosystems (Schnitzer and Carson, 2001).
Swidden agriculture, which was widely practiced for centuries throughout much of Bhutan, increases the number and frequency of gaps and the proportion of secondary vegetation associated with fallows. Therefore, it influences the abundance and distribution of flora and fauna, particularly when it is a dominant land use (Finegan and Nasi, 2004). Researchers unbiased by anti-swidden sentiments suggest that swidden systems maintain high levels of biodiversity (Padoch and Pinedo-Vasquez, 2010). Indeed, a recent re-evaluation of the ecological role and importance of swidden cultivation asserts that:

‘Shifting cultivation has transformed a great part of the “natural” landscapes of the eastern Himalayas into cultural landscapes with their own unique biodiversity. It is now impossible to distinguish between “natural” or “pristine” forests and human-influenced or “secondary” vegetation… people themselves are probably at least partly responsible for the wealth of biodiversity that is now present. Forest farmers are often found to have an enriching influence on natural vegetation’ (Kerkhoff and Sharma, 2006. p40).

Two types of swidden were historically practised in Bhutan: *tseri*, a tree or bush-fallow system at low to mid elevations (500-2500m) and *pangshing*, a grass-fallow system at higher elevations (2500-3500m) (see Roder et al, 1992 and Dukpa et al, 2007 for detailed descriptions). As recently as the early 1990s, *tseri* and *pangshing* covered approximately 200,000ha of Bhutan (Roder et al, 1992). However, that declined to about 45,000ha by the early 2000s (Dukpa et al, 2007). Swidden farming declined throughout Bhutan as a consequence of: 1) a lack of farm labour due to rural-to-urban migration, particularly among young adults; 2) increased road access and market opportunities which led farmers to abandon historic, subsistence food-crop production in favour of cultivating higher-value export cash crops; and 3) a Royal Government of Bhutan policy to prohibit and phase out *tseri* by the end of 1997 (Dukpa et al, 2007; Wangchuk and Siebert, 2013). A recent meta-analysis of land-cover transformations around the world also found that swidden agriculture decreases in landscapes with access to markets that encourage cattle production and cash cropping (van Vliet et al, 2012). However, there is limited spatial documentation of the decline of swidden or discussion about whether these or additional factors continue to limit its use.

**Research site and methods**

We focus our study in Bumthang and Zhemgang districts of Central Bhutan, where swidden was widely practised for many generations (specifically *pangshing* in Bumthang and *tseri* in Zhemgang, according to Dukpa et al, 2007). In particular, we document changes in the area under swidden cultivation and in forest cover, and reasons given for these changes by local farmers at two sites, Nasiphel (2900m) in
Bumthang district and Shingkhar (1400m) in Zhemgang district between 1989 and 2011.

To document changes in the extent of swidden cultivation and forest cover we used paired Landsat imagery in a 25sq-km area surrounding each village between 1989 and 2010. The images, which were acquired on February 13, 1989 (Landsat 4) and February 15, 2010 (Landsat 5), were calibrated to reflectance (Gaynesh et al., 1989) to allow comparisons over the intervening years. Additionally, a Normalized Difference Vegetation Index was calculated (NDVI rationale from Tucker, 1979) and added to the satellite data. We then visually interpreted the imagery and identified areas that showed apparent swidden loss between the years 1989 and 2010. Finally, NDVI values were extracted for those areas to evaluate landscape changes associated with swidden loss and forest encroachment.

The Normalized Difference Vegetation Index (NDVI) is a commonly used index in remote sensing to evaluate vegetated surfaces. It is a ratio index that is calculated by:

\[
NDVI = \frac{(NIR - Red)}{(NIR + Red)}
\]

where NIR = near-infrared reflectance (Landsat Thematic Mapper band 4, 0.76 – 0.90µm) and Red = red reflectance (Landsat Thematic Mapper band 3, 0.63-0.69µm).

In contrast with other terrestrial surface and atmospheric features, vegetation reflects highly in the near-infrared, while absorbing red wavelengths. This allows the discrimination of vegetation from other features (e.g. bare rock, water or clouds) that show very different reflective characteristics. Additionally, NDVI provides an assessment of vegetation condition and is often used as a surrogate for many biophysical parameters. Examples include: leaf area index (e.g. Myneni et al., 1997), photosynthetic activity (e.g. Running and Nemani, 1988) and biomass (e.g. Box et al., 1989).

In order to provide insights into changes in swidden practices and forest cover observed over recent decades, we interviewed elderly residents at each village that local people identified as the most knowledgeable about long-standing agricultural practices. The interviews, conducted in November and December 2011, involved five people in Nasiphel, two of whom were women, and three in Shingkhar, all of them men. The interviews were not a random sample and hence cannot be generalized.

Based on the observed and reported changes in swidden practices and forest cover, and published accounts of disturbance attributes associated with historic swidden practices (from Dukpa et al., 2007 and Roder et al., 1992), we evaluated the potential effects the changes in historic swidden-disturbance regimes may have had on flora and fauna in these locations.

Results

Based on visual interpretation of satellite imagery, there are clear changes associated with swidden loss in the study areas. Polygons identified as areas of agriculture
change (loss of swidden) totalled 54.17ha (2.17% of the 25sq-km area) in the Nasiphel region and 18.51ha (0.74%) in Shingkhar (figures 1 to 7). Additionally, NDVI values were extracted from the identified areas to preliminarily assess how vegetation was changing and data were extracted from areas adjacent to our ‘study sites’ to serve as controls. Initial evaluation of mean change over time indicates that the areas interpreted as swidden loss show increases in the NDVI trajectory that are consistent with a transition from agriculture to forest-cover types, where biomass, leaf area index and photosynthetic activity are increasing. The control site, in contrast, showed NDVI values that remained consistent over time (table 1).

All of the elderly interview respondents reported that significant changes in agriculture and forest cover had occurred over the past two decades. All noted that swidden farming had ceased and forest cover had increased, and that while agriculture now occupied less land than in the past, it is more intensive (i.e., it involves the use of commercial fertilizers and improved varieties) and is commercially oriented (i.e., producing cash crops for market rather than for subsistence consumption). This is particularly the case in Nasiphel, which has had road, and hence, market access for years.

FIGURE 1  Overview of 2010 image, acquired February 15 2010 from Landsat 5 Thematic Mapper (Row 41, Path 137) Circles indicate 25sq-km buffer around Nasiphel and Shingkhar
FIGURE 2 Subset of 2010 image. Buffers around Nasiphel and Shingkhar shown by circles

FIGURE 3 Subset of 1989 image, acquired February 13 1989 from Landsat 4 Thematic Mapper (Row 41, Path 137) Circles represent 25sq-km areas around Nasiphel and Shingkhar

FIGURE 4 1989 image with buffer and areas delineated as lost swidden agriculture near Nasiphel

FIGURE 5 2010 image with buffer and areas delineated as lost swidden agriculture near Nasiphel
Disturbance attributes associated with swidden agriculture in Nasiphel and Shingkhar are summarized in Table 2. It is noteworthy that swidden farming created disturbances that were significantly larger than natural disturbances, particularly tree falls, and that extensive early seral vegetation was maintained at both sites. Swidden fields were typically greater than 0.5ha, often adjacent to one another, and irregularly shaped (based on Landsat imagery and the statements of elderly farmers). These conditions are likely to have favoured flora and fauna that prefer disturbed, high-light environments. With the decline in swidden agriculture, dense, +/- even-aged stands of blue pine and broadleaf forests have established at Nasiphel and Shingkhar, respectively.

Discussion

Historic livelihood activities and associated ecological-disturbance regimes have changed in Nasiphel and Shingkhar over the past two decades. According to

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Twenty-year mean NDVI values for areas exhibiting swidden loss and control sites in Nasiphel and Shingkhar, Bhutan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Swidden-loss sites</strong></td>
<td><strong>1989 mean NDVI</strong></td>
</tr>
<tr>
<td>Nasiphel + Shingkhar combined</td>
<td>0.380</td>
</tr>
<tr>
<td>Nasiphel</td>
<td>0.344</td>
</tr>
<tr>
<td>Shingkhar</td>
<td>0.480</td>
</tr>
<tr>
<td>Control Sites</td>
<td></td>
</tr>
<tr>
<td>Nasiphel + Shingkhar control combined</td>
<td>0.569</td>
</tr>
<tr>
<td>Nasiphel control</td>
<td>0.523</td>
</tr>
<tr>
<td>Shingkhar control</td>
<td>0.627</td>
</tr>
</tbody>
</table>

*Note: Nasiphel ‘lost’ 54.17ha of swidden, or 2.17% of the 25sq-km study area; Shingkhar ‘lost’ 18.51ha of swidden, or 0.74% of the 25sq-km study area.*
TABLE 2 Disturbance attributes associated with swidden (tseri and pangshing) in Nasiphel and Shingkhar, Bhutan

<table>
<thead>
<tr>
<th>Type</th>
<th>tseri</th>
<th>pangshing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location/elevation *</td>
<td>500-2500m</td>
<td>2500-3500m</td>
</tr>
<tr>
<td>Forest type</td>
<td>warm and cool broadleaf</td>
<td>blue pine</td>
</tr>
<tr>
<td>Size</td>
<td>variable, all &gt; 0.5 ha, many &gt; 1.0 ha</td>
<td></td>
</tr>
<tr>
<td>Intensity x</td>
<td>cut, burnt, not ploughed</td>
<td>cut, burnt and ploughed</td>
</tr>
<tr>
<td>Duration (yrs) x</td>
<td>1-2 of cultivation</td>
<td>2-3 of cultivation</td>
</tr>
<tr>
<td>Frequency yrs x</td>
<td>2 - 8 of fallow</td>
<td>6 - 20 of fallow</td>
</tr>
<tr>
<td>Shape</td>
<td>variable</td>
<td>variable</td>
</tr>
<tr>
<td>Spatial distribution</td>
<td>usually adjacent to other cultivated fields and/or fallsows</td>
<td></td>
</tr>
<tr>
<td>Vegetation (swidden)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop x</td>
<td>maize, millet, rice</td>
<td>buckwheat, wheat</td>
</tr>
<tr>
<td>Fallow x</td>
<td>shrubs, trees, annuals</td>
<td>grasses, forbs, blue pine</td>
</tr>
<tr>
<td>Seral stage</td>
<td>early successional/perennials</td>
<td>early successional/grass</td>
</tr>
<tr>
<td>Plant regeneration</td>
<td>coppicing, seed bank, seed rain</td>
<td>all vegetation eliminated, seed rain</td>
</tr>
<tr>
<td>Vegetation (2011)</td>
<td>dense broadleaf forests</td>
<td>dense blue pine</td>
</tr>
</tbody>
</table>

Note: Disturbance attributes marked with an ‘x’ are from Dukpa et al, 2007 and Roder et al, 1992; other attributes based on field observations and discussions with knowledgeable older farmers at the two sites.

knowledgeable older residents, swidden agricultural practices ceased in Nasiphel due to 1) improved road and market access, which stimulated farmers to switch from cultivating a diversity of annual food crops for domestic household consumption to high-value cash crops for sale, principally potatoes (cited by all five elderly farmers) and 2) the Royal Government of Bhutan’s decision to eliminate swidden throughout the country by 1997 (cited by two farmers). Adult male migration to urban areas to seek work is widely known as a cause of farm-labour shortage across the Himalayas (Saxena et al, 2005). However, in Nasiphel it seems to be largely young people – both male and female – who leave. In Shingkhar, elderly farmers stated that swidden agriculture ceased due to 1) limited household labour resulting from young people leaving for urban areas to join the army, attend school or find work (cited by all three elderly farmers) and 2) preparations to produce and sell market crops pending road and market access (also cited by all three farmers). The differences between the two communities are not surprising as a rough road reached Nasiphel in the late 1990s, while Shingkhar expects to have farm road access in 2013. It is also noteworthy that all eight elderly farmers at both sites stated that the climate had warmed significantly in their lifetimes and that as a result new crops were now able to be cultivated (particularly paddy rice and chilli in Nasiphel).

Using NDVI values (table 1) as a surrogate for and a measure of forest encroachment in former swidden areas supports the observed (i.e., Landsat) and farmer-reported
evidence of land-use change. The mean NDVI values for both sites (Nasiphel and Shingkhar) show an increase over the 20-year period, which would be expected in an area that transitioned from agriculture to forest. This interpretation is supported by the fact that the acquisition dates occur in winter when agriculture NDVI values would likely be low and forested areas higher. In contrast, the forested ‘control’ sites show similar NDVI values over the 20-year period. These forested ‘control’ sites exhibit NDVI scores similar to the 2010 values in areas where swidden has been lost, thus suggesting transition to forest. When the sites are considered individually, Shingkhar, the more southerly, shows a greater increase in vegetation (NDVI difference = 0.219 vs 0.175). This north-south difference likely corresponds to a general increase in productivity and vegetation vigour associated with lower elevations and more southerly sites.

The cessation of swidden agriculture altered historic ecological-disturbance regimes that were at least partially responsible for the development and maintenance of flora and fauna (i.e., biodiversity) in both locations. The end of swidden-associated disturbances is manifest in the significant increase in forest cover, decrease in cultivated area and reduction in the number of farm parcels observed between 1989 and 2010 at both sites. The specific effects associated with these changes include: 1) widespread establishment of dense, +/- even-aged forests (blue pine in Nasiphel, broadleaf forest in Shingkhar); 2) reduced grass, forbs, shrubs and other early successional vegetation; and 3) a reduction in the extent of forest-gap edges. All of the elderly farmers in both sites noted that forest cover had increased significantly in recent decades and two farmers at Nasiphel stated that as a consequence of the increased forest cover, crop predation by deer and pigs was much more severe than in the past.

At a landscape level, there has been a transition in vegetation cover at both Nasiphel and Shingkhar. Whereas it was once a complex mosaic of cultivated swidden fields, a diversity of seral vegetation up to 20 years of age associated with swidden fallows, and uncultivated closed-canopy primary forests, it now consists of more homogeneous, dense, closed-canopy forests. The disturbance attributes associated with swidden agriculture differ markedly from ‘natural’ tree falls. In particular, tseri- and pangshing-created gaps that were much larger than tree falls, and swidden fields were typically located adjacent to other cultivated and/or fallowed fields (table 1). Consequently, historic swidden disturbances maintained more open fields and a greater proportion of secondary vegetation in a variety of successional stages than presently exists.

The biodiversity implications associated with these changes have yet to be documented, but we suggest they are potentially profound. In general, the establishment of dense, closed-canopy forests favours interior, forest-dependent flora and fauna and is poorly suited to plants and animals that prefer gaps or high-light environments. While the specific habitat requirements of most of Bhutan’s diverse flora and fauna are unknown, tigers – a flagship umbrella species of domestic and international conservation concern – are habitat generalists whose populations are strongly influenced by the availability of prey (Khan et al, 2007; Kanagaraj et al, 2011; Wikramanayake et al, 2011). The preferred prey of tigers in Bhutan includes various
ungulates (e.g., sambar and musk deer) and wild pigs. Interestingly, more evidence of tigers (i.e., scats, tracks and camera-trap photos) was recorded in disturbed secondary forests associated with swidden cultivation than in dense, undisturbed forests in Jigme Singye Wangchuck National Park in central Bhutan (Namgyel et al, 2008). Research in the nearby Terai of Nepal and India found that the most parsimonious model of habitat selection by tigers incorporated habitats suited to their two main prey species – spotted deer and sambar – both of which favour open forests and grasslands, where browse and forage are more abundant (Kanagaraj et al, 2011). Similarly, Khan and Chivers (2007) concluded that tigers in Bangladesh benefitted from habitat diversity because that maintained populations of their preferred prey, spotted deer and wild pig. Studies in Nepal found that open Sal forests, tall grass, mixed grasslands, upper bench Sal forests, mixed deciduous forests, Siwalik Hills and dry river courses provided the best tiger habitat (Smith et al, 1998). None of these are dense closed-canopy forests. Even more interesting is a recent study in Nepal’s Chitwan National Park, which found high tiger densities both within and outside the park, notwithstanding ubiquitous and abundant humanity (Carter et al, 2012). Could forest disturbances associated with small-scale farming and grazing increase the availability of forage and browse for wild ungulates, thereby providing tigers with more prey? Finally, a recent analysis of potential tiger population densities concluded that dry deciduous forests and alluvial savannas/grasslands could support significantly higher tiger population densities than rainforests, subtropical broadleaf, pine and other dense, closed-canopy forests (Wikramanayake et al, 2011). While these results might be expected of a habitat generalist, it is noteworthy that blue- and chir-pine forests in Bhutan also exhibit relatively low bird species diversity and contain no specialist species (Inskipp et al, 1999).

The recent land-use and forest-cover changes documented in Nasiphel and Shingkhar represent a significant departure from historic disturbance regimes that may result in reduced annual- and woody-species diversity and less productive habitat for many animal species in addition to tigers. Furthermore, the establishment of dense, homogenous, closed canopy forests is widespread. For example, more than 28% of the area long inhabited by indigenous swidden farmers in Jigme Singye Wangchuck National Park was in cultivated or fallowed swidden fields in 1989, but only 6% remained in 2005 (Namgyel et al, 2008). A recent nation-wide land cover assessment reveals that total forest cover in Bhutan increased from 72% in 1995 to 81% in 2010, while the area of cultivated agricultural land declined from 7.85% to 2.93% (NSSC & PPD, 2011). These results are similar to our observations in Nasiphel and Shingkhar. Elsewhere in the eastern Himalayas, Salick et al (2005) documented widespread abandonment of agriculture and increased tree growth associated with government afforestation programmes and suppression of burning in Tibet, which resulted in a shift of the tree line into alpine meadows and an influx of fire intolerant plant species that are unpalatable, indigestible or poisonous to domestic and wild ungulates. Similarly, Xu et al (2009) observed a significant shift from open to closed canopy forests and a decline in biological diversity associated with swidden fallows.
in southwest China between 1993 and 2006. Finally, Saxena et al. (2005) noted that there has simultaneously been large-scale outmigration leading to abandonment of agricultural land and change from subsistence to market economies and cash crop cultivation throughout much of the Himalayas.

The contribution of swidden-associated disturbance to biological diversity is most significant at the landscape level. While fallow vegetation and other early successional forests are structurally less diverse than primary forest, landscapes that incorporate swidden disturbances are more structurally diverse than primary forest alone, and habitat modifications associated with swidden tend to increase faunal diversity at many spatial scales (Finegan and Nasi, 2004). The converse also appears to be the case; that is, the cessation of historic swidden agriculture may affect floristic and faunal diversity. For example, the recent decline in traditional milpa (i.e., swidden) agriculture due to rural-to-urban migration in Oaxaca, Mexico has resulted in reduced spatial heterogeneity of forest structure with potentially significant implications for the conservation of native flora and fauna (Robson and Berkes, 2011).

It is noteworthy that swidden farming is only one previously widespread historic anthropogenic disturbance that is changing in Bhutan. Changes in historic grazing are likely to have even greater ecological significance because of the larger proportion of total land area affected. For centuries, yak and cattle grazed under traditional cultural-management practices throughout much of the country, from subtropical and warm broadleaf forests below 1000m to alpine meadows above 5000m. Extensive livestock grazing and its associated ecological disturbances, like swidden farming, tend to increase landscape heterogeneity, reduce the abundance and density of tree cover, and favour the establishment and growth of grasses and other early successional vegetation. The decline in floristic diversity and structural heterogeneity associated with the end of extensive livestock grazing and swidden also means the loss of wild foods, fibre, medicinals, and other materials used by local households.

Conclusions

The biodiversity effects associated with changes in swidden, a key historic anthropogenic disturbance in Bhutan, are potentially profound, but uncertain and largely unknown. The intimate relationships between historic livelihood practices and the abundance and distribution of flora and fauna, and basic ecological processes and functions, argues for a concerted effort to understand, document and monitor current conditions and the transformations now occurring across the landscapes of Bhutan and the eastern Himalayas more generally. As dynamic social-ecological systems, this necessitates a multi-disciplinary and multi-scaled approach. It is imperative that this inquiry commence soon while sites still subject to historic anthropogenic ecological-disturbance regimes persist and individuals with longstanding traditional ecological knowledge that helped to create and maintain these landscapes and their associated biological diversity are still living and able to participate in the research.
References


NSSC and PPD. (2011) *Bhutan Land Cover Assessment 2010* (LCMP-2010), Ministry of Agriculture and Forests, Bhutan


