3. The Future of Southeast Asian Forests and their Species

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Introduction
Southeast Asia faces a widely recognized biodiversity crisis. The crisis has two principal causes. The first is habitat loss caused by land use change and, in particular, by the conversion of forested lands to agriculture (Myers et al., 2000; Brooks et al., 2002). Land use conversion affects all species that depend on forest habitats. The second principal cause of the Southeast Asian biodiversity crisis concerns the direct persecution of animals for meat, for the pet trade, and for their mystical value in several cultures (Cerlett, 2007). Habitat loss and direct persecution threatens many Southeast Asian forest species with local, regional and even global extinction (Sodhi et al., 2004). The Southeast Asian biodiversity crisis has been exacerbated by the spectacular collapse of a number of forest reserves (e.g., Smith et al., 2003; Corbin et al., 2004). The conspicuous failure of nature reserves heightens the sense of crisis against the backdrop of high rates of deforestation and unsustainable rates of harvesting of many game species.

The potential loss of species through their global extinction is nowhere greater than in Southeast Asia due to the high levels of endemism in the region (Sodhi et al., 2004). Myers et al. (2000) identify 25 global hotspots of endemism. Each hotspot contains at least 0.5% or 1,500 of the world's 300,000 plant species as endemics that are found nowhere else. The eleven countries of Southeast Asia are, with the sole exception of Indonesia, New Guinea, entirely included inside four of the hotspots. The hotspot of Sundaland includes Brunei, Malaysia, Singapore and the large Indo-Malayan islands of Sumatra, Java and Borneo. The hotspot of Wallacea includes Timor-Leste and the other large Indonesian islands. The hotspot of the Philippines includes the country with the same name. And, the hotspot of Indo-Himalaya includes all of Viet Nam, Laos, Cambodia, Thailand, and Myanmar with small extensions into the southern parts of China, India and Assam and along the foothills of the Himalayas to Nepal. Altogether 29,332 plant species or 9.7% of the global total and 2,276 terrestrial vertebrate species or 8.3% of the global total are endemic to just one of these four hotspots (Myers et al., 2000). A conservation crisis that extends across these four Southeast Asian hotspots has serious implications for the preservation of global biodiversity.

Here, we will examine the first and most pervasive cause of the present-day biodiversity crisis in Southeast Asia — habitat loss — and estimate the proportion of forest endemic species threatened with extinction as a consequence. To accomplish this, we will first review past levels of forest loss in Southeast Asia, examine characteristics of the forest that remains in Southeast Asia today, and explore three possible scenarios for future changes in forest cover. We will also consider alternative assumptions about the habitat requirements of species that influence their vulnerability to extinction in light of ongoing forest loss and the characteristics of the forests that remain in Southeast Asia today and are expected to remain in the future. The different scenarios and assumptions lead to very different — albeit all arguably high — estimates of the proportion of species threatened with extinction today and in 2050. The uncertainty in these estimates highlights the critical need to resolve certain unknowns to help ensure that scarce conservation resources are deployed most effectively. Our country-specific analyses of remaining total and primary forest area, the rate of

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change of total and primary forest area, and the area and effectiveness of nature reserves also lead to specific suggestions for where conservation investments are most urgently needed today.

A tool to quantify species extinctions caused by land use change

Conservation biologists use a newly universal relationship between the area (A) of a habitat and the number of species (S) found there to predict numbers of endemic species threatened with extinction when land use change reduces habitat area (Pimm et al. 1995, Brooks et al. 2002). This relationship is well described by a power function, \( S = CA - \beta \), where \( C \) and \( \beta \) are empirically determined constants. When land use change occurs, species dependent on the diminished habitat face a reduction in area from its original value, \( A_{original} \), to a new and lower value, \( A_{new} \). Thus, the original species area relationship, 
\[ S_{original} = C A_{original}^{-\beta}, \]

is replaced with a new altered species area relationship, 
\[ S_{new} = C A_{new}^{-\beta}, \]
which implies a new lower number of species. Dividing the new relationship by the original relationship, we can predict the proportion of endemic species expected to survive in the newly reduced area of habitat as follows:

\[ S_{new}/S_{original} = (A_{new}/A_{original})^{-\beta}. \tag{1} \]

We will use Equation 1 as a heuristic tool to predict the proportion of Southeast Asian endemic species that will survive given different future values of \( A_{new} \). We will calculate the original, pre-agricultural area of forest, \( A_{original} \), from a 5-minute resolution global vegetation cover map derived from the 1-km resolution DISCovered land cover dataset supplemented, where crops dominate cover, by the IHOME3 vegetation cover model (Hasselquist and Preece 1996, Loveland and Belward 1997, Remansky and Feeley 1999). The value of \( \beta \) falls between 0.25 and 0.35 in many studies, with values close to 0.25 being typical for fragmented landscapes created by land use change.

We will use several different values of \( A_{new} \) to complete Equation 1. The values of \( A_{new} \) will reflect three future scenarios for the extent of forest loss and a range of assumptions concerning the dependence of endemic species on different forest types. The three future scenarios for the extent of forest loss will be described later (see Scenarios for future changes in forest cover). The three forest types will contrast the original, undisturbed primary forest and human altered forests. We will allow the proportion (P) of endemic species dependent on primary forest to vary continuously from 0 to 1.

We will assume that the remaining endemic species (a proportion equal to 1-P) are also able to tolerate human-altered forests but not croplands. Land use change will never threaten species able to tolerate croplands and towns. To incorporate this habitat dependence, we will partition \( A_{new} \) into undisturbed, primary forest (\( A_{primary} \)) versus disturbed, logged forests plus naturally regenerating secondary forests (\( A_{secondary} \)), so that \( A_{new} = A_{primary} + A_{secondary} \). The proportion of endemic species expected to survive in the new mixture of habitats follows:

\[ S_{new}/S_{original} = P \cdot (A_{primary}/A_{original})^{-\beta} + (1-P) \cdot (A_{secondary}/A_{original})^{-\beta}. \tag{2} \]

The compléments of Equations 1 and 2 are the proportions of endemic species threatened with global extinction due to land use change and habitat loss.

Three caveats qualify the application of Equations 1 and 2 to predict species loss. First, the true threat to Southeast Asian species will be underestimated because habitat loss is just one, albeit the most important, of several drivers contributing to the Southeast Asian biodiversity crisis (Sothi et al. 2004). Second, the threat will be overestimated because an unknown proportion of endemic species are able to tolerate croplands and towns and will not be threatened by land use change. Finally, complications are introduced when land use change divides the remaining habitat into many small fragments. Small fragments of habitat spread widely over the original forested area will include the ranges of more species than will a single block of habitat of the same total area; however, a single, large block of habitat has greater potential to maintain species with large territories or large minimum viable population sizes. Our and other regional applications of Equation 1 to predict species loss ignore these complications (e.g., Pimm et al. 1995; Brooks et al. 2002). These caveats emphasize our intent to use Equations 1 and 2 as heuristic tools to compare conservation outcomes under different scenarios and thereby to isolate critical areas where additional knowledge is required to invest conservation resources effectively.

Present day forest loss and the threat of extinction in Southeast Asia

1. Total forest cover today — a first prediction

Over the past 300 years, the development of copland in Southeast Asia has come almost exclusively from the conversion of formerly forested lands to become copland (Figure 1). There was a very low level of conversion between 1700 and 1850; however, since 1850 forest conversion to copland has increased at an exponential rate. If we had no other information than that provided in Figure 1, Equation 1 would predict that 10.3% (\( = 1 - (A_{original}/A_{new})^{1/\beta} \)) of the endemic species of Southeast Asian forests would eventually become extinct due to past reductions in forest area. Of course, the total forest area graphed in Figure 1 includes not only primary forest but also secondary forest and plantations, and thus would lead to underestimates of extinction rates for species that require the original primary forest cover. The exponential increase in land use conversion since 1850 is also cause for serious concern should it continue into the future. We now address these issues.

2. Primary forest cover today — a refined prediction

The United Nations Food and Agricultural Organization (FAO) characterizes present-day forest reserves and being primary forest, modified natural forest, semi-natural forest, or plantations for 230 countries and territories including the 11 Southeast Asian countries (Table 1). Primary forest includes forests of native trees "where there are no obviously visible indications of human activities and the ecological processes are not significantly disturbed." The endorses to Table 1 provide the FAO definitions of each forest category with examples.

![Figure 1: Changes in Southeast Asian land cover since 1700.](image)
We can now use Equation 2 and the total aggregate figures in Table 1 corrected by removing Indonesian New Guinea to predict the loss of endemic species from Southeast Asian forest caused by land use conversion. The potential forest cover (or \(A_{pot}\)) for the region after removing Indonesian New Guinea is 3,619,118 km² (Table 1). Thus, Equation 2 predicts that past forest loss threatens the eventual extinction of 51% of the Southeast Asian endemic species that require primary forest to survive. The situation is less dire for endemic species able to tolerate human altered forests. We include modified natural and semi-natural forest cover as suitable habitat for those more tolerant species and exclude plantations because most plantations consist of single introduced tree species. Henceforth, we will use secondary forest to refer collectively to modified natural and semi-natural forests. The percentage of species threatened with extinction decreases from 51% to 45%, 39%, 32%, 28% and 19% as the percentage of species tolerant of secondary forests increases from 0% to 20%, 40%, 60%, 80% and 100%, respectively.

<table>
<thead>
<tr>
<th>Country</th>
<th>Potential Forest Cover (km²)</th>
<th>Total Forest (km²)</th>
<th>Primary Forest (km²)</th>
<th>Modified Natural Forest (km²)</th>
<th>Semi-Natural Forest (km²)</th>
<th>Plantations (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>5220</td>
<td>2,780</td>
<td>2,780</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cambodia</td>
<td>164,000</td>
<td>108,470</td>
<td>3,220</td>
<td>100,660</td>
<td>0</td>
<td>990</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,700,000</td>
<td>884,940</td>
<td>487,029</td>
<td>397,911</td>
<td>0</td>
<td>363,940</td>
</tr>
<tr>
<td>Laos</td>
<td>22,000</td>
<td>16,428</td>
<td>14,900</td>
<td>144,289</td>
<td>0</td>
<td>2,240</td>
</tr>
<tr>
<td>Malaysia</td>
<td>324,000</td>
<td>208,900</td>
<td>38,200</td>
<td>114,970</td>
<td>0</td>
<td>15,730</td>
</tr>
<tr>
<td>Myanmar</td>
<td>668,000</td>
<td>322,320</td>
<td>0</td>
<td>333,160</td>
<td>0</td>
<td>5,490</td>
</tr>
<tr>
<td>Philippines</td>
<td>280,000</td>
<td>71,620</td>
<td>8,290</td>
<td>51,310</td>
<td>0</td>
<td>6,200</td>
</tr>
<tr>
<td>Singapore</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thailand</td>
<td>499,000</td>
<td>145,200</td>
<td>64,510</td>
<td>40,700</td>
<td>0</td>
<td>30,990</td>
</tr>
<tr>
<td>Total</td>
<td>4,039,650</td>
<td>2,083,870</td>
<td>619,797</td>
<td>778,560</td>
<td>518,910</td>
<td>125,610</td>
</tr>
</tbody>
</table>

The percentage of endemic species predicted to become extinct varies by nearly three-fold from 39% to 51% depending upon the percentage of those species able to tolerate human altered forests. This last difference highlights the need to understand species responses to habitat degradation and to move beyond the simplistic assumption that all species require undisturbed, primary forest. Of course, forest cover is not static, which leads us to consider scenarios for future forest cover change.

Future forest loss and the threat of extinction in Southeast Asia

1. Scenarios for future changes in forest cover

We will use three different scenarios to project forest cover forward from 2005 to 2030. The first scenario is the "business as usual" scenario proposed by N. Sudoh, B. Brook and their colleagues (Sudoh et al. 2004; Brook et al. 2006) They assume "the annual percentage rate of forest loss (l) remains constant" to project future Southeast Asian forest loss. Thus, with \(l\) expressed as a proportion, the area of forest remaining in 2030 (\(A_{pot}\)) equals \(A_{pot} \times (1 - l)^{10}\). Brook et al. (2006) use a Southeast Asian wide annual percentage rate of forest loss of 1.4%. Thus, the "business as usual" scenario predicts a further decline in forest area of nearly 30% (1.4 - (1 - 0.14)^10) by 2030

The two remaining scenarios project future forest cover from predicted changes in human population density and present-day relationships between forest cover and human population density (Wright and Muller-Landau 2006a). Figure 2 presents the relationship between potential forest cover remaining in 2000 and rural population density in 2000 for Southeast Asia and neighboring tropical countries. The neighboring countries extend the observed range of population density, and their inclusion improves the proportion of variation explained by the relationship without altering the form of the relationship. We will use this relationship and also the similar relationship with total (urban + rural) population density to project forest cover forward from 2005 to 2030. We emphasise that we repeat these projections for both rural and total (urban + rural) population densities (Wright and Muller-Landau 2006a). The argument for using rural population density is that rural people clear forests, and, perhaps even more importantly, rural people maintain open landscapes by preventing natural secondary succession that would quickly re-establish forest cover in humid Southeast Asia. The argument for projecting future forest cover using total (urban + rural) population density is that it is ultimately demand for food and other products that drives deforestation, and that this demand arises from the total population. The percentage of Southeast Asians living in urban settings was 15% in 1950 and 39% in 2000 and is predicted to rise to 61% in 2030 (Figure 3; United Nations 2004). This intense urbanisation raises the possibility that urban demand for food and other products might contribute more to deforestation at sites remote from urban centers in the future as the ratio of urban to rural population densities increases. Thus, we repeat our projections of future forest cover using both the predicted increase in rural population density and the predicted increase in total (urban + rural) population density. The United Nations Population Division has predicted both rural and urban population change for every member country forward to 2030 (United Nations 2004). To project future forest cover for Southeast Asia, we will first use the population changes predicted for 2030 for each country to project future forest cover from the present-day relationships between forest cover and both rural and total (urban + rural) population density and then sum the country-level values (Wright and Muller-Landau 2006a). A crucial question remains, which is how to project changes in primary as well as total forest cover into the future.

2. Changes in primary forest cover from 1990-2005

Past changes in primary forest cover might suggest how to project future changes in primary forest cover. The FAO (2006) reports the area of primary forest present in each Southeast Asian country in 1990, 2000 and 2005 (Table 2). The value reported for Singapore is an order of magnitude higher than the value normally accepted for primary forests in Singapore (Corlett 1997). This suggests that tall secondary forest has been included. It is widely believed that prehistoric human activities altered most tropical forests (reviewed by Wright and Muller-Landau 2006a), and it is reasonable to assume that the FAO data for primary forests include tall secondary forests as well as pristine primary forests for most countries. Henceforth, we will use primary forest as defined by the FAO.
The primary forest cover remaining and its loss between 1990 and 2005 varied widely among the eleven Southeast Asian countries (Table 2). Myanmar, Singapore and Timor-Leste lacked or virtually lost primary forest in 1990. Cambodia and Viet Nam are on track to join these countries. Primary forest covered 4% of its pre-agricultural area in Cambodia in 1990 and 58% of this was lost by 2005. Primary forest covered just 1.5% of its pre-agricultural area in Viet Nam in 1990 and a stunning 76% of this was lost by 2005. Indonesia has the largest intact forest resource base in Southeast Asia, and an intermediate rate of loss. Primary forest covered 41% of its pre-agricultural area in Indonesia in 1990 and declined by 31% by 2005. Indonesian primary forest is largely in New Guinea, and we are unable to separate Indonesian New Guinea from the 15-year record of primary forest cover change in Table 2. This period saw large forest losses in Borneo and Sabah, however (Smith et al. 2003, Curnut et al. 2004), so much of this change fell within Southeast Asia. The five remaining countries offer more reason for hope. Primary forest covered 59% of its pre-agricultural area in Brunei in 1990 and 11% of this was lost by 2005. Finally, the Lao People’s Democratic Republic, Malaysia, the Philippines, and Thailand reported modest amounts of primary forest in 1990, which ranged from 3% to 18% of pre-agricultural forest area and no loss of primary forest over the next 15 years (Table 2). Primary forest will take centuries to regenerate, and its ongoing loss is a conservation tragedy in Indonesia and Brunei and particularly in Cambodia and Viet Nam.

These recent observed changes in primary forest area suggest country-specific projections of future primary forest area. This approach will be difficult to implement, however, because Indonesian New Guinea, which contributes more than half of the primary forest cover of the 11 Southeast Asian countries, cannot be isolated from the Indonesian data (Table 2). We will therefore consider the role played by forest reserves in each country.

3. Forest reserves and primary forest cover

Effective forest reserves will prevent the loss of primary forests within their boundaries. This raises two questions relevant to projections of future primary forest cover in Southeast Asia: First, do the forest reserves of Southeast Asia support primary forest? And, second, are they effective?

Several Southeast Asian countries have impressive systems of nationally and internationally recognized forest reserves (Table 3). The World Conservation Union and the United Nations Environment Programme Synthesize information on all protected natural areas in the World Database on Protected Areas (WDPA) Consortium 2004) The WDPA is incomplete, but it is the best globally comprehensive data available on protected areas. Wright et al. (in review) used Geographic Information Software to superimpose the global distribution of 18 biomes (Olson et al. 2001) onto the boundaries of every reserve included in the WDPA. This includes all Southeast Asian reserves whose boundaries are included to the WDPA, and that include tropical or subtropical coniforous, dry broadleaf or moist broadleaf forest biomes. Malaysia has another 31 reserves whose boundaries are not yet entered in the WDPA. Indonesia, the Philippines, Thailand, and Viet Nam are among the top ten tropical countries for members of forest reserves, and Indonesia and Thailand are among the top ten for the area of forest protected. Although the WDPA is incomplete, these top rankings are unlikely to change. Cambodia, Laos, and the Lao People’s Democratic Republic, the Philippines and Thailand have all protected more than 10% of their potential, pre-agricultural forest area, and Viet Nam has protected more than 8% (Table 3). This represents a remarkable commitment to conservation.
Table 3: The forest reserves of Southeast Asia. Number of reserves refers to reserves that include tropical rainforest, dry broadleaf or moist broadleaf forest whose boundaries are listed in the World Data Base on Protected Areas. Number Rank is the ranked value of Number of Reserves among 70 countries with reserves that meet these criteria. Area is the measured area of forest in those reserves. Area Rank is the ranked value of Area among the same 70 countries. Percentage (BAI) of Potential Forest Area equals Area divided by Potential Forest Cover (Table 1). Ratio of Reserve Area to Primary Forest Area equals Area divided by Primary Forest Cover in 2005 (Table 1).

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Reserves</th>
<th>Number Rank (of 70)</th>
<th>Area of Reserves (km²)</th>
<th>Area Rank (of 70)</th>
<th>Percentage of Potential Forest Area</th>
<th>Ratio of Reserve Area to Primary Forest Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>7</td>
<td>39</td>
<td>41</td>
<td>65</td>
<td>1.54</td>
<td>0.029</td>
</tr>
<tr>
<td>Cambodia</td>
<td>50</td>
<td>19</td>
<td>45,045</td>
<td>11</td>
<td>27.5</td>
<td>0.140</td>
</tr>
<tr>
<td>Indonesia</td>
<td>264</td>
<td>1</td>
<td>181,414</td>
<td>2</td>
<td>10.6</td>
<td>0.372</td>
</tr>
<tr>
<td>Laos</td>
<td>21</td>
<td>21.5</td>
<td>36,873</td>
<td>12</td>
<td>16.7</td>
<td>2.47</td>
</tr>
<tr>
<td>Malaysia</td>
<td>23</td>
<td>20</td>
<td>113,377</td>
<td>25</td>
<td>3.51</td>
<td>0.298</td>
</tr>
<tr>
<td>Myanmar</td>
<td>3</td>
<td>52.5</td>
<td>2,080</td>
<td>44</td>
<td>0.344</td>
<td>0.414</td>
</tr>
<tr>
<td>Philippines</td>
<td>155</td>
<td>2</td>
<td>33,512</td>
<td>14</td>
<td>12.0</td>
<td>4.04</td>
</tr>
<tr>
<td>Thailand</td>
<td>102</td>
<td>5</td>
<td>66,784</td>
<td>6</td>
<td>14.2</td>
<td>1.64</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>78</td>
<td>9</td>
<td>20,180</td>
<td>19</td>
<td>8.07</td>
<td>23.7</td>
</tr>
</tbody>
</table>

What type of forest is found inside these reserves? The final column of Table 3 presents the ratio of the summed areas of reserves that overlap forest biomes in the area of primary forest in 2005 for each country. The forest reserves of Cambodia and Viet Nam are 14-fold and 25-fold larger than the area of primary forest in 2005, respectively. The forest reserves of the Lao People’s Democratic Republic and the Philippines are 2-5-fold and 4-fold larger than the area of primary forest in 2005, respectively. Reserves in these four countries include mainly human altered forests. On the other hand, the forest reserves of Brunei, Indonesia, Malaysia and Thailand might protect largely primary forests.

There is widespread concern that these reserves are paper parks unable to protect the forests within their boundaries. Wright et al. (in review) assessed the effectiveness of Southeast Asian forest reserves by superimposing reserve boundaries and daily satellite-based fire detections provided for the entire globe by the Moderate Resolution Imaging Spectroradiometer (Justice et al. 2002). Many human activities increase the low background incidence of fire in tropical forests. These activities include logging, which increases fuel load; forest fragmentation, which increases the number of fire prone forest edges; and agriculture, which involves fire to clear and manage land. A simple visual comparison of the number of fires detected inside forest reserves and just outside those reserves provides a first indication of the level of success of those reserves. Figures 4, 5 and 6 present every fire detected in 2002, every protected area registered in the World Data Base on Protected Areas (WDPA Consortium 2004), and the distribution of biomes following Olson et al. (2001) for Cambodia, Malaysia and Indonesian Borneo and Java, respectively. The large number of fires inside several forest reserves and the general lack of any inhibitory effect of reserves on the number of fires suggest that Cambodian reserves are failing (Figure 4). There are virtually no fires inside Malaysian forest reserves, and Malaysia provides a stellar example of what should be possible in all Southeast Asian countries (Figure 5). The reserves of Indonesian Borneo are widely recognized to be critical (Smith et al. 2003; Curnoe et al. 2004) and the fire numbers confirm this (Figure 6). Two reserves in eastern Java with very large numbers of fires include active volcanoes that trigger the satellite-based fire detection algorithm repeatedly. Otherwise, Javan reserves approach the standard for success set by Malaysia (Figure 6). The very high numbers of fires in reserves in Cambodia and Borneo are also observed in Guatemala, Paraguay and Sierra Leone.

(Wright et al., in review). Reserves are in crisis in these countries. The low number of fires observed inside reserves for Malaysia and Java also characterises Costa Rica, Ghana, Jamaica, South Africa and Taiwan (Wright et al., in review). Reserves in these countries appear to be much more successful although other threats that do not increase fire frequency (e.g. hunting) await evaluation.

To summarise, the reserve data demonstrate a strong initial commitment to conservation by at least five Southeast Asian countries in establishing reserves that cover more than 8% of their potential forest area (Table 3). However, most of the forest inside these reserves has been altered by humans in Cambodia, the Lao People’s Democratic Republic, the Philippines and Viet Nam, and, with the exception of Malaysia, the effectiveness of reserves at protecting primary forest is uncertain (Figures 4-6; Wright et al. in review). For these reasons, our projections for future forest cover change will not consider existing forest reserves.

Figure 4: Fires, forest reserves and biomes of Cambodia. Fires were detected by the satellite-based Moderate Resolution Imaging Spectroradiometer during 2002. Each forest reserve registered with the World Data Base on Protected Areas is presented in dark gray. Biomes are moist broadleaf tropical forest (white) and dry broadleaf tropical forest (gray). The large number of fires inside several forest reserves and the general lack of any inhibitory effect of reserves on the number of fires suggest that several Cambodian reserves are failing.
Figure 5: Forestry reserves and biomes of Malaysia. Peninsula Malaysia is to the left, Sabah and Sarawak are to the right. See caption to Figure 4 for further explanation.

4. Projecting future changes in primary forest cover

Having concluded that forest reserves provide little insight into future changes in primary forest cover, the country-level changes in primary forest cover observed between 1990 and 2005 (Table 2) could still guide projected changes in primary forest cover. One possible scenario might entail 2005 primary forest cover for the four countries that lost no primary forest between 1990 and 2005, reducing primary forest cover to zero for Cambodia and Vietnam, and maintaining a constant proportional or constant absolute state of primary forest cover loss for Brunei and Indonesia. We are, however, unable to extract New Guinea from the Indonesian primary forest cover data. Because New Guinea contributes more than half of the primary forest cover of the 11 Southeast Asian countries, this presents an insurmountable problem. For this reason, we will fall back on the simplest possible assumption. We will assume that total forest cover and primary forest cover decrease in lockstep. This assumption will understate future primary forest cover where effective nature reserves disproportionately protect primary forest and will overestimate future primary cover where people disproportionately clear primary forest. The latter is occurring in Amazonia Brazil (Wright and Muller-Landau 2006a). With these caveats in mind, we will implement one scenario for future forest with proportionate losses to total and primary forest cover.

Projecting the future threat of extinction due to land use change

We will now use the complement of Equation 2 to project the threat of global extinction caused by land use change for Southeast Asian endemic species in 2030. Changes in forest cover will be projected forward to 2030 beginning with the area in primary and secondary forest in 2005 for each Southeast Asian country (Table 1, excluding Indonesia New Guinea) and each of the three scenarios described previously (see scenarios for future forest cover change). For each scenario, we will project forest cover separately for primary and secondary forest and then use the complement of Equation 2 to evaluate the sensitivity of the apparent extinction crisis to the proportion of endemic species that are dependent upon undisturbed primary forest. Because rural populations are actually declining in Southeast Asia (Figure 3), the rural population model projects increases in total forest area. We forced all increases in forest area to be for secondary forests and did not allow primary forest area to increase above levels observed in 2005. We removed Indonesia New Guinea throughout. Table 4 summarises the observed values of forest cover in 2005, projected values of forest cover for 2030 for the three scenarios, and the proportion of endemic species predicted to be threatened with global extinction for three levels of land use change when every species is dependent upon primary forest and when every species is also able to tolerate secondary forests.
Implications for conservation in Southeast Asia

The projections in the final two paragraphs of Figure 3 are sobering. The most optimistic scenario considered suggests that 18% of the endemic species of Southeast Asia will be threatened with global extinction due to land use change in 2010. This represents nearly 3,300 species of plants and more than 400 species of amphibians, reptiles, birds and mammals. If the rate of habitat loss continues, the extension of many of these species will be limited to small patches of land. The extinction of all endemic species are able to survive in secondary forest and the area of primary forest holds constant while the area of secondary forest increases as rural populations decline. This scenario is overly optimistic. The percentage of threatened species rises to 22% if increasing total (urban + rural) populations cause primary and secondary forest area to decline to and 26% under the business as usual scenario. If endemic species are unable to tolerate secondary forest and are instead entirely dependent on primary forest, the percentages of threatened species increase by two to three fold to 51%, 55% and 53% under the three scenarios, respectively. In addition, habitat loss is just one, albeit the most important, of the threats to Southeast Asian biodiversity (Sodhi et al. 2004).

The extinction of somewhere between 20% and 60% of the endemic species of Southeast Asia is possible.

Many conservationists anticipate even worse outcomes (Díez et al. 2002; Sodhi et al. 2004). The three scenarios considered here all anticipate a decline in absolute deforestation rates (Wright and Muller-Landau 2006a,b). Absolute rates of conversion of intact primary forests to human cultured logged forests increased in Indonesia in the wake of the economic and political crises of the 1990s (Smith et al. 2003). Absolute rates of conversion of virgin land to cropland might increase if global markets created new demand for Southeast Asian agricultural products. The global market for caoba (a unique forest to cropland might increase if global markets created new demand for Southeast Asian agricultural products. The global market for caoba (Inga edulis) is driving similar increases in cropland along the southern margin of the Amazon today (reviewed by Wright and Muller-Landau 2006a). Transmigration programs that move people from low to less densely populated parts of Indonesia are perhaps the greatest threat that might increase absolute deforestation rates in Southeast Asia today. The form of the relationship in figure 2 illustrates the dangers of transmigration programs. Forest cover is linearly related to the logarithm of population density. Thus, given the slope of the relationship observed in Figure 2, a doubling (or halving) of population density is associated with a decrease (or increase) of just 12% in remaining forest area. The log-linear form of this relationship means that multiplicative changes in human population density cause arithmetic changes in remaining forest area. Transmigration policies can cause human population density to increase by several hundred percent at their destination but to decrease by a few tenths of a percent at their source. For this reason, transmigration programs wreak havoc on the forests of Indonesia. These examples illustrate how government programs (transmigration), global markets and political and economic crises might exacerbate forest loss and increase the threat of extinction in Southeast Asia.

What steps can be taken to avoid these outcomes? There are three obvious answers. The first is to protect the last remnant of primary forest in Cambodia and Viet Nam. Our efforts to reduce the loss of primary forest in Brunei and Indonesia (Table 2). The second is to raise the effectiveness of existing forest reserves in Cambodia, Indonesian Borneo and other Southeast Asian countries to the levels realised in Malaysia (Figures 4-6). The third is to increase the number of forest reserves in Brunei and Malaysia to the high levels observed in other Southeast Asian countries (Table 3). These three steps plus the ongoing protection of the remaining primary forests of the Lao People’s Democratic Republic, Malaysia, the Philippines and Thailand (Table 2) could set Southeast Asia on course to realize the more optimistic outcomes in Table 4.

Yet, the most optimistic outcomes in Table 4 still anticipate the extinction of thousands of plant species and hundreds of vertebrate species. This is unacceptable, and solutions must be sought. The logic of the species-area relationship dictates a single viable solution — increase the area of forested habitat. Species threatened with extinction by human disturbance are often found in decades to centuries as small yet ultimately unsustainable populations (Pimm et al. 1995). This presents a window of opportunity to re-establish conditions that will permit their long-term survival. The immense diversity of Southeast Asia that is now underway (Figure 4) provides just this opportunity. The concentration of people in urban centers will allow natural secondary succession to re-establish forests and might offset conservationists and governments the opportunity to purchase lands for conservation. In other cases, the pace of reforestation of these lands can be enhanced through simple cost-effective measures including the addition of seeds of selected species whose seed dispersal agents might be missing (Lamb et al. 2005).

The extraordinary concentration of valuable timber poses a severe problem for the conservation of primary forest in Southeast Asia. Each protected primary forest represents an untapped economic opportunity for the timber industry, and loggers will remove timber illegally whenever political and economic conditions permit (Smith et al. 2003; Carwardine et al. 2004). The concentration of valuable timber in primary forests means that conservationists must seriously consider the conservation value of logged and secondary forest in Southeast Asia. Conservation biologists routinely assume that every endemic species is entirely dependent on undisturbed, primary forest (Myers et al. 2000; Brooks et al. 2002; Sodhi et al. 2004). Wright and Muller-Landau (2006a) made the opposite assumption to highlight the need for research to determine the habitat requirements of tropical species for primary versus human altered forests. Figure 7 illustrates the sensitivity of the extinction curves caused by habitat loss to the assumption of species absolute requirement for primary forest versus tolerance of logged and secondary forests. There are indications that many Southeast Asian species tolerate logged forests (Cannon et al. 1998; Mejía, et al. 2005) and this offers hope that future increases in forest area combined with measures to re-establish and re-establish the species composition of old-growth forests can still prevent the loss of 80% or more of the endemic species of Southeast Asia.

References
4. Northern Australia — All That Water ... Going To Waste?

S.E. Bunn

Introduction

Humans already use about half of the world’s annual renewable freshwater resource — some 4,000 km$^3$ — yet over 40% of the world’s population suffers from water shortage, over a billion people lack access to safe drinking water and nearly 3 billion do not have access to adequate sanitation (Postel et al. 1996; Postel 1998; UNESCO 2006). Changes to the global climate have resulted in lower rainfall and higher evaporation in some regions, diminishing surface water supplies. Increased pollution of waterways has compounded the problem further by reducing availability of safe, clean water. To add to this mix the increasing demand for water for food and energy production and there is little wonder we face a global water crisis (Vörösmarty et al. 2000).

There is little wonder too that our rivers and wetlands are now considered to be the most threatened ecosystems on the planet (Malaynat and Ruddell 2002; Postel and Richter 2003). In much of the world, humans have transmuted river corridors for urban and agricultural land use to the extent that many floodplains are functionally extinct from their rivers (Tockner and Stanford 2002; Tockner et al. in press). Most of the world’s larger river systems have been moderately or heavily fragmented by dams and flow regulation (Nilsson et al. 2005). This has had major impacts on river bio, especially migratory species (Pringle 2001), and on coastal fisheries (Leranger and Bunn 1999). Inconcessions in nitrogen loading from cities and agriculture have translated into order of magnitude increases in riverine fluxes to the coastal zone (Green et al. 2004). These cumulative impacts of a growing human population are the direct reason why freshwater systems have the highest rates of extinction of any ecosystem, e.g. as much as 4% per decade in North America (based on data sets for unamended rivers, trout, and amphibians) (Ricard and Rasmussen 1990). More than 20% of all freshwater species of fish are either threatened or endangered. This is particularly significant considering that freshwater habitats support 6% of all described species, including approximately 40% of fish diversity and 15% of the vertebrate diversity (Dodson et al. 2006).

Water resource management issues in Asia

The future of rivers and wetlands in Asia is of particular concern. Freshwater withdrawals from lakes and rivers have increased at a far greater rate than anywhere else in the world and most of this (80%) is used for agriculture (UNEP 2001). Contamination by pollutants has effectively reduced the availability of clean freshwater from about 10,000 km$^3$ in the 1950s to about 4,000 km$^3$. One in three Asians has no access to safe drinking water, one in two has no access to safe sanitation and only 10% of sewage is treated at least to a primary level. The region reports more than 500,000 infant deaths per year due to dirty water and poor sanitation. Recent estimates are that US$8 billion is required yearly until 2015 if the region is to meet the Millennium Development Goal targets for water supply and sanitation (double that to cover all people) (Arvinis and Fox 2003). Note that this equates to an investment of just over US$2 per person per year.

At present, Asia has 10 out of the world’s 19 megacities, with populations of 10 million or more. In most countries, urban populations will probably triple in the next four decades resulting in an estimated five-fold increase in domestic demand for water (UNEP 2001).

Endnotes

1 Primary forest cover includes forests of native trees — where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Non-wood forest products might be collected, and some trees might have been removed.

2 Modified natural forest cover includes "but is not limited to: selectively logged-over areas, naturally regenerating areas following agricultural land use, areas recovering from human induced fires, etc. — areas where it is not possible to distinguish whether the regeneration has been natural or assisted."

3 Semi-natural forest includes "areas under intensive management where native species are used and deliberate efforts are made to increase/optimise the proportion of desirable species, thus leading to changes in the structure and composition of the forest. Naturally regrown forests from other species than those planted/seeded may be present.

4 Plantations include “introduced species and in some cases native species, established through planting or seeding, mainly for production of wood or processed goods” or “the provision of services” Plantations include all stands of introduced species established purposefully and “areas of native species characterised by few species, straight tree lines and/or even-aged stands”.

5 Includes Indonesia: New Guinea which supports 415,000 km$^2$ of forest, which is presumably all listed as primary forest (see Primary forest cover in 2001 — a refined prediction).

6 Indonesia: New Guinea.

7 Myanmar has 54 protected areas. The WPAI includes the boundaries of just these.

8 Secondary forest area equals the sum of modified natural and semi natural forest area from Table 1.
Water crisis in Australia?

Australians consider water conservation and management as the single most important environmental issue facing the nation today. From a global perspective, it must be difficult to appreciate why. Even though Australia has the distinction of being the driest inhabited continent, we have abundant freshwater resources relative to our small population size. Australia is in the top 20% of countries in terms of total renewable water resources with more than 10 times the water availability per person compared to India, China, South Africa and even the UK, and twice as much as the USA (UNESCO 2006). We also have the dam capacity to store more water per capita than any other country (Commonwealth of Australia 1996). So why the talk of a water crisis?

In part, the problem is that most Australians choose to live where the water isn’t. About two-thirds of the available freshwater is in our tropical north – over 246,000 GL (cubic km) of run-off, of which just over 1% is currently diverted (NLWRA 2001). This is in stark contrast to the 24,000 GL available in the Murray-Darling Basin of which over half is currently diverted. To compound matters, the water is not always there when we want it because our rainfall is highly variable between years. Australia is without question a land of droughts and flooding rains.

However, to a large part, the problem is one of our own making. Australia has one of the highest rates of water use in the world – third after the USA and Canada. Although much of this (about two-thirds or nearly 17,000 GL) is in the agricultural sector, our domestic consumption is staggering – the national household average is over 300 litres per day per person (ABS 2004). This is about double the average use per person in the UK and even higher than our American counterparts (around 260 litres per day). Interestingly, the average per capita household use in the Northern Territory is nearly double the Australian average. Where does it all go? About 40% of the water delivered to our doors is poured onto gardens, 15% goes down the toilet and a similar amount is used in the laundry – less than 10% is used in the kitchen (ABS 2004).

Threats to Australia’s tropical freshwater resources

There is little doubt that, in the short term, construction of dams and other barriers, alterations to flow regimes and isolation of floodplains from agricultural and urban development are likely to have a far greater impact on freshwater ecosystems than climate change per se in most parts of the world (Macleay and Rustule 2002; Fockner and Stanford 2002).

However, it is worth noting that the potential impacts to tropical freshwater ecosystems from projected changes in the Australian climate are of some concern. Significant losses of coastal freshwater wetlands are expected, especially in northern Australia, as sea levels rise as predicted. Many of northern Australia’s freshwater lagoons are low-lying and vulnerable to projected sea-level rises of 10-30 cm (Bayliss et al. 1997), because of the expansion of tidal channel networks and the increased risk from storm surge increases in average temperatures will directly affect the distribution of tropical forest stream birds, many of which are cool steppes species with highly restricted distributions (e.g. some mountain crows and flocks) are at risk.

Although there is a real risk to northern Australia’s freshwater ecosystems from climate change, the more serious threat comes from the processing of those that are being wasted. There have been repeated calls in the press for proposals to address this perceived problem, including recent ‘rad fired’ schemes involving pipelines or canals and even super-tankers to capture river water flowing unchecked from our northern tropical rivers into flood thirty cities in the south (e.g. the Kimberley Pipe Line). Not only have these proposals been shown to be uneconomical, they are based on the false premise that ‘water flowing to the sea is wasted’ Such proposals ignore the considerable ecosystem goods and services provided by natural river flows and the wetlands and estuaries they sustain (Forster and Carpenter 1997; Wilson and Carpenter 1998). Some of these services, including productive recreational and commercial fisheries and tourism, can easily be valued in economic terms. Others that relate to biodiversity, cultural or spiritual values cannot, and hence are not considered in economic decision-making.

We demeans them by trying (Arrejo-Agudo 2005). As a society, we are becoming increasingly aware that these grand proposals come with unacceptable environmental and social costs.

Challenge of ecologically sustainable water management

What then can be done to meet this tremendous challenge? Instead of consuming water as if there is no tomorrow, we must make better use of the resource we have. It is clear from the recent water restrictions in our southern cities that considerable savings can be made and more could be done with the right incentives.

Unfortunately, changing behaviour alone will not be enough in the face of a rapidly growing population and increased uncertainty of supply. Less than 1% of our total water use currently comes from wastewater and most of that goes to agriculture and industry (ABS 2004). This is too valuable a resource to continue to be pumped into the sea and we should move quickly to create opportunities for greater spate by industry and agriculture. Similarly, we can do much to reduce stormwater run-off from urban areas, including the adoption of water-sensitive design in new urban areas and reticulating in the existing urban footprint. These measures will not only help solve our urban water supply problem but also help to improve the health of waterways downstream (e.g. Abi et al. 2005).

Governments are already exploring these and other options but is there something more we can do to assist? City-dwellers can undoubtedly help by reducing water use in their homes. However, we can do far more by actively contributing to open and informed debate about the future use of our water resources. This should not simply be a debate about how we supply our thirsty cities. At the national scale, urban dwellers are not the real water guards. Household water consumption accounts for only 9% of the total water use in Australia, compared with 67% used in agriculture (ABS 2004). The rice industry alone uses almost as much as all Australian households combined (about four times the volume of Sydney Harbour) – dairy and cotton use far more. Much of this agricultural production is exported, representing a virtual trade of thousands of gigalitres of water shipped overseas. For example, the million tonnes of rice exported each year represents an export of between 1,000 to 1,500 GL of water from our already water stressed river systems. Such industries support important regional economies but this international trade has come at the expense of the health of our rivers. As we have seen with the Murray River, much of the considerable cost of environmental repair is left to the taxpayers. As the irrigation sector looms to the tropical north for new opportunities, it is timely to consider whether we can afford to allow the same to happen again.

Conclusion

The real water crisis in Australia is that we have yet to come to appreciate the true value of our freshwater assets. As scientists, we must become better at clearly articulating the true values of freshwater – including the rivers, wetlands and coastal ecosystems that depend on it, and the goods and services they provide. There is an urgent need to convince the people of Australia and especially their decision makers that the vast water resources in northern Australia that sustain these important assets are not ‘wasted’. If we continue to treat water as a cheap commodity and our rivers in little more than tubes that carry it to the sea, then our opportunity to overcome these challenges will be lost, and we will watch our future go down the drain.

References


What are the Changes and their Impacts?

Prepare for Impact!


5. Time's Up for Australia's Last Frontier

* D M J S Bowman

**Introduction**

Frontiers are by their very nature odd places because the singular purpose of life on the frontier is change. Debra Bird Rose (1997) described the transformative energy of the frontier as the moment when history and meaning is made de novo. King Malcondo (2000) grasped the intoxicating effect of frontier life for individuals. Writing about the Northern Territory in the 1940s she observed that the Territory was 'a tremendous stage with a handful of players, and the opportunity for everyone to have a starring role, to write the drama as they go along.' On frontiers the only certainty is change itself - in one or two generations heroic, vital and purposeful frontier lifestyles can be reduced to pathetic, marginal lives, as is powerfully portrayed in Arthun Miller's *The Misfits.* With calculated irony, Miller (1961) has some of the last of the wild west 'cowboys' dying a living killing wild hares for pet food. With so much change, attachments to place are obliterated as those places are changed - it is no coincidence that Xavier Herbert entitled his northern Australian magnum opus *Poo Poo Fellow My Country.*

Alida Leapold (1949), the father of the modern environment movement, understood the inherent contradiction of the American frontier life when he wrote that 'pioneers usually scoff at any effort to perpetuate pioneering' Yet, without consideration of how a frontier is being developed, and strenuous effort to conserve the natural and cultural values of the frontier, are we not doomed to repeat the same mistakes as have occurred on other frontiers? Simply put, will northern Australia be a replica of the 'development' of southern Australia?

For 150 years, there has been a remarkable confluence of a 40 millennia old culture and western traditions in northern Australia, associated with the west wave of colonisation by the British Empire. The economic drivers of northern settlement in the 19th century were geopolitical, strategic imperatives, localised mining and extensive cattle ranching on the 'endless landscapes' (Powell 2000). Infertile soils, labour shortages, livestock diseases and isolation from markets stymied intensive agricultural developments. In consequence, only a tiny portion of the northern Australia savannas were subject to land clearing, in dramatic contrast with the transformation of landscapes witnessed in southern Australia during the same period

For the first half of the 20th century, the north remained an exotic backwater - aptly described as a 'fetal frontier' by Cathy Robinson (2005) because hunting of feral buffalo for hides and crocodiles for skins were major primary industries. These 'fetal' industries were a dramatic manifestation of a social and biological frontier that both separated, and united, black hunter-gatherers with white civilisation and modernity (Robinson 2005). The future of the north was so far outside the Australian political consciousness that it was beyond serious consideration. However, sustained attacks by the Japanese during the Second World War forced the Australian government to grapple with the 'problem' of the north. In the post-war period, the Australian government explored the economic potential of the vast 'empty' and 'unproductive' landscapes. Using technological approaches, land capability was assessed and heroic attempts at agriculture and forestry swallowed up considerable sums of Commonwealth money, to no avail (Ridpath et al 1991).

In the early 1990s, Ridpath et al (1991) declared that the transition from Aboriginal to settler Australian citizenship was incomplete and that the north remained a colonial frontier. They wondered whether the north was too hostile for European settlement, yet they recognised that this...