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Diminishing Habitats in Regions of High Biodiversity

In this chapter, we review the loss of native habitats across the tropics: the region that lies between the Tropics of Cancer and Capricorn, i.e. 23.5° north and south of the equator (Figure 1.1). The word 'tropics' is derived from the Greek word *tropos* meaning 'turn'. The average annual temperature of the tropics is higher and the seasonal change in temperature is less pronounced than in other parts of the world because the tropical zone receives the rays of the sun more directly than areas at higher latitudes. The seasons in the tropics are marked not by large temperature fluctuation, but by the combination of winds taking water from the oceans and creating seasonal rains, called monsoons, over the eastern coasts. Several different climatic types can be distinguished within the tropical belt. Distance from the ocean, prevailing wind conditions and elevation are all contributing elements. Tropical highland climates, which have some characteristics of temperate climates, also occur where high mountain ranges are located. The tropics are the world's largest reservoirs of humid forests (Amazon, Congo Basin and New Guinea); the immense vegetative growth of these lush 'rain forests' is attributable to the monsoon rains. Owing to decreasing rainfall towards the northern and southern limits of the tropics, climatic conditions favour low-latitude savannah, steppe and desert biomes. High temperatures and abundant rainfall make rubber (*Hevea brasiliensis*), tea (*Camellia* sp.), coffee (*Coffea robusta* and *C. arabica*), cocoa (*Theobroma cacao*), spices, bananas (*Musa* sp.), pineapples (*Ananas* sp.), oils and timber the leading agricultural exports of tropical countries.

Ironically, the tropical region where two-thirds of the world's biodiversity is found is also the backdrop of massive contemporary loss of native habitats, mimicking the historical land conversion witnessed over the past few centuries in Europe and the temperate regions of North America and Australia. As a result of this mega-rich biodiversity and unprecedented loss of habitats, the tropical region has obviously attracted a high level of interest from conservationists. We first present an overview of habitat loss, namely in rain forests, mangroves and tropical savannas, and then follow with a report on the known and postulated

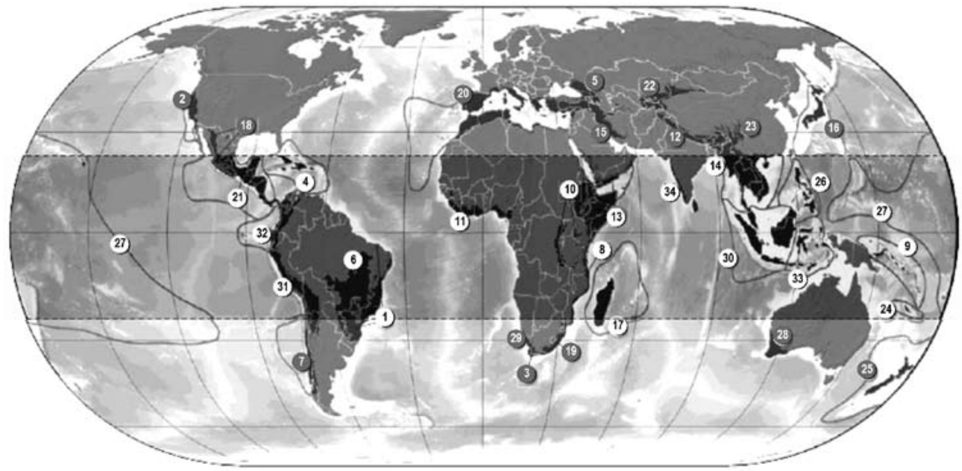


Figure 1.1 A map of the world showing the tropics and the distribution of 'biodiversity hotspots' outside (grey circles) and within (white circles) the tropics (shaded region): 1, Atlantic forest; 2, California floristic province; 3, Cape Floristic region; 4, Caribbean islands; 5, Caucasus; 6, Cerrado, 7, Chilean winter rainfall – Valdivian forests; 8, coastal forests of eastern Africa; 9, East Melanesian islands; 10, eastern Afromontane; 11, Guinean forests of west Africa; 12, Himalaya; 13, Horn of Africa; 14, Indo-Burma; 15, Irano-Anatolian; 16, Japan; 17, Madagascar and Indian Ocean islands; 18, Madrean pine–oak woodlands; 19, Maputaland–Pondoland–Albany; 20, Mediterranean basin; 21, Mesoamerica; 22, mountains of Central Asia; 23, mountains of southwest China; 24, New Caledonia; 25, New Zealand; 26, Philippines; 27, Polynesia–Micronesia; 28, southwest Australia; 29, Succulent Karoo; 30, Sundaland; 31, tropical Andes; 32, Tumbes–Chocó-Magdalena; 33, Wallacea; 34, western Ghats and Sri Lanka. (After conservation.org. Copyright, Conservation International.)

drivers of native habitat loss in the tropics. Finally, we identify the areas in immediate need of conservation action by discussing the concept of biodiversity hotspots.

1.1 Loss of native habitats

If human impact on the natural environment continues unabated at its present rate or increases in severity, then by the turn of the century the resulting changes in land use will have exerted a profound and irreversible effect on tropical biodiversity (Sala *et al.* 2000). Habitat loss will probably have far greater effects on terrestrial ecosystems in the tropics than other drivers such as climate change, elevated carbon dioxide (CO_2) levels and invasive species (Sala *et al.* 2000). However, among these factors there are likely to be large and complex interactions that exacerbate the foreseen problems. Rain forest loss, degradation and fragmentation are the most widely publicized examples of habitat loss in the tropics; indeed, human activities, such as logging, are degrading and destroying tropical rain forests at a rate that has no historical precedence (Jang *et al.* 1996; Whitmore 1997; W.F. Laurance 1999). Given that the vast majority of the earth's terrestrial biodiversity is harboured in these threatened and little-studied biomes (E.O. Wilson 1988; Myers *et al.* 2000; Sodhi and Liow 2000), they are critical for conservation.

1.1.1 Rain forest depletion

Tropical forests cover 7% of the earth's land surface, yet they support over 50% of described species, plus a large number of undescribed taxa (W.F. Laurance 1999; Dirzo and Raven 2003). They are also critical for global carbon and energy cycles [Intergovernmental Panel for Climate Change (IPCC) 2002]; therefore, tropical forests are not only crucial for biodiversity conservation, they also play pivotal roles in moderating global climate change. Despite this importance, more than 40% of original tropical forests have been cleared in Asia alone (Wright 2005).

The United Nations Food and Agriculture Organization (FAO) has reported that countries with the largest annual net forest losses between 2000 and 2005 are all situated in the tropics (FAO 2005). These countries include Brazil, Indonesia, Sudan and Myanmar, and they collectively lost 8.2 million hectares (ha) of forest every year between 2000 and 2005 (FAO 2005). W.F. Laurance (1999) used data provided by the FAO (1993) on forest cover change from 1980 to 1990 and estimated that 15.4 million ha of tropical forest is destroyed every year, with an additional 5.6 million ha being degraded through activities such as selective logging. Overall, an average of 1.2% of existing tropical forests is degraded or destroyed every year (Whitmore 1997; W.F. Laurance 1999). In terms of absolute loss of area, forest conversion is the highest in the neotropics (South and Central America: 10 million ha/year), followed by Asia (6 million ha/year) and Africa (5 million ha/year). However, if we consider forest conversion relative to the existing forest cover in the region, Asia clearly tops the list (W.F. Laurance 1999) (Figure 1.2), with 1.5 million ha of forest removed each year from the four main Indonesian islands of Sumatra, Kalimantan (Indonesian

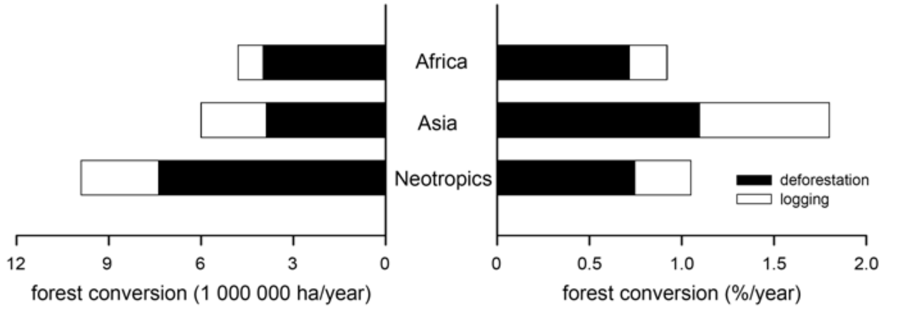


Figure 1.2 Relative and absolute rates of forest conversion in the major tropical regions throughout the decade of the 1980s. (After W.F. Laurance 1999. Copyright, Elsevier.)

Borneo), Sulawesi and West Papua (Indonesian New Guinea) alone (DeFries *et al*. 2002). Even the so-called 'protected forests' in the tropics are not safe from plunder – of 198 protected areas surveyed, 25% have been losing forests within their administrative boundaries since the 1980s (DeFries *et al*. 2005).

Worryingly high as they are, whether the FAO values are accurate is controversial because they may fail to include catastrophic events (such as the vast 1997–98 forest fires that occurred in Indonesia) and may erroneously include forestry plantations as native forest cover (Matthews 2001; Achard *et al.* 2002). Deploying remotely sensed satellite imagery, Achard *et al.* (2002) reported that tropical forest loss may be much lower (5.8 million ha/year) than FAO estimates. Yet even Achard *et al.*'s estimates have being questioned. It has been argued that their lower estimates of forest loss may be unrepresentative, owing to the fact that they sampled only 6.5% of the humid tropics (Fearnside and Laurance 2003). Nevertheless, despite the different methodologies used, Achard *et al.* (2002) also found, as reported earlier by W.F. Laurance (1999), that rates of deforestation and forest degradation are highest in Asia (Figure 1.3).

The expansion of agriculture in the humid tropics is the main culprit in this devastating forest loss, with more than 3 million ha of forest converted annually by this activity (Achard *et al.* 2002). Although native forest loss in tropical Latin America seems to be decelerating, in a particularly disconcerting trend it continues to accelerate in tropical Asia (Matthews 2001) (Figure 1.4). This trend is further corroborated by a satellite imagery study of Latin America, tropical Africa and Asia by M.C. Hansen and DeFries (2004), who reported that deforestation appears to be accelerating in the last two regions (Figure 1.5). Depending on factors such as soil fertility and proximity to remnant forests (i.e. seed source), forest regeneration can proceed in abandoned areas following disturbance (Chazdon 2003). These secondary forests could be crucial for global carbon cycles and conservation of some forest biota (Wright 2005). However, about a quarter of regenerating forests are also being lost in tropical Asia and Africa (M.C. Hansen and DeFries 2005), with an increase of this forest type found only in Latin America (Figure 1.5).

There has also been controversy as to whether the global deforestation rate is subsiding over time. FAO data show that globally there has been a 31% decrease

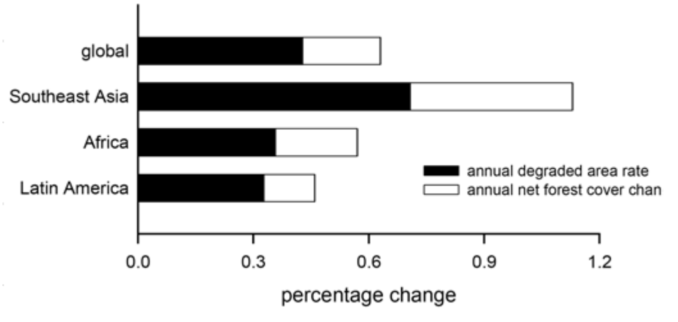


Figure 1.3 Mean annual estimates of deforestation in the humid tropics from 1990 to 1997. (Data derived from Achard *et al.* 2002.)

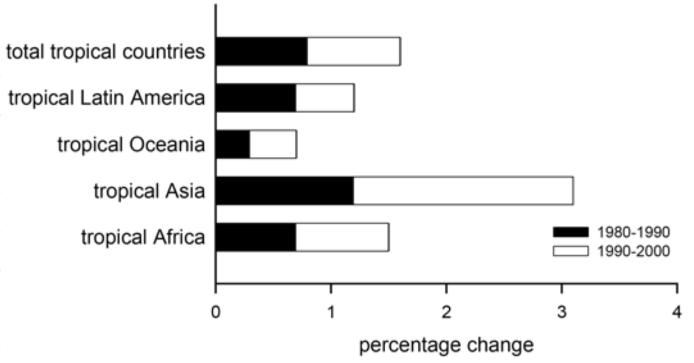


Figure 1.4 Worsening deforestation rates in all tropical regions except Latin America. (Data derived from Matthews 2001.)

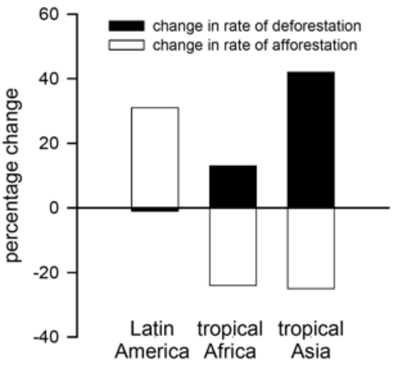


Figure 1.5 Positive increase in rate of deforestation (filled bars) and decrease in rate of afforestation (blank bars) in tropical Africa and Asia, with only Latin America showing opposite trends. (Data derived from M.C. Hansen and DeFries 2004.)

in the deforestation rate over the past two decades. But a study by M.C. Hansen and DeFries (2004) showed that deforestation has, in reality, accelerated by the same amount during the same period. Wright and Muller-Landau (2006) argue that the deforestation rate will slow down in the future due to a decrease in human population growth and increasing migration to urban centres. They argue that such changes in human demographics will be conducive to forest regeneration. However, Brook *et al.* (2006a) dispute this scenario because of decoupling between rural and urban human populations (Figure 1.6); even if deceleration does occur, it may be a little too late to stop the mass extinction of biodiversity in the tropics caused by the momentum of past habitat loss (see Chapter 9).

Globally, 0.8% of native tropical forests (primary and secondary forests, excluding plantations) are likely to be lost each year (Matthews 2001), and in countries plagued by civil war, such as Burundi and Rwanda, the rates of loss

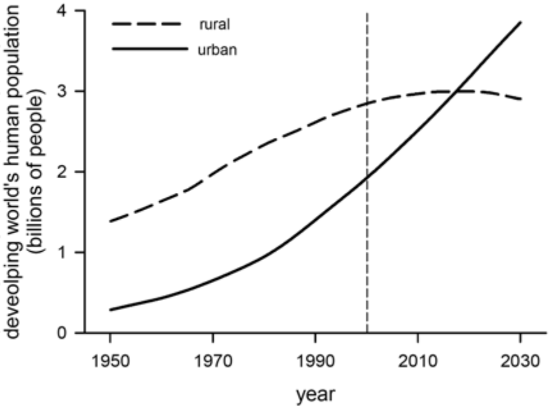


Figure 1.6 Trends in rural and urban human population growth in the world's developing countries. Vertical dashed line separates past and projected figures. (After Brook *et al.* 2006a. Copyright, Blackwell Publishing Limited.)

can be much higher (Table 1.1). Perhaps most dramatically, it has been estimated that by 2010 human actions will have caused almost complete destruction of native lowland (< 1000 m elevation) forests from the hyper-biodiverse regions of Sumatra and Kalimantan (Jepson *et al.* 2001). Such a massive loss of habitat will almost certainly have profound incidental effects on the region's spectacular mega-fauna, such as the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), Sumatran tiger (*Panthera tigris sumatrae*) and Asian elephant (*Elephas maximus*). Tropical countries with the highest deforestation rates (> 0.4% deforestation annually) usually have a large percentage of the remaining dense forests (> 80% canopy cover) near deforestation activities, thus indicating that these areas also remain highly vulnerable to deforestation (M.C. Hansen and DeFries 2004) (Figure 1.7).

The lowland tropical rain forests are particularly imperilled owing to their ready accessibility to an expanding human population and their increasing conversion to logging concessions, agricultural land and urban areas (Kummer and Turner 1994). In addition to this widespread forest type, other forest types also existing in the tropics are being destroyed (Whitmore 1997) (Figure 1.8). For example, montane/submontane (usually > 1000 m elevation) rain (cloud) forests provide timber, fuel wood, soil and catchment protection. This forest type makes up 12% of the existing tropical forests worldwide, and it is currently being cleared at a rate twice that of the global average [Long 1994; Whitmore 1997; IUCN (The World Conservation Union) 2000]. In fact, montane forests are lost at a relatively higher annual rate than lowland tropical forests (Figure 1.9) (Whitmore 1997). Montane forests, because of their unique environmental conditions (e.g. cooler temperatures), support a high degree of endemism. For example, the proportion of endemic moths is at least twice as high in montane forests than in their lowland counterparts in Malaysian Borneo (Chey 2000). Montane forests have a low recovery potential following disturbance (Ohsawa 1995; Soh *et al.* 2006). However, despite their fragility and high endemism,

Table 1.1 Summary information on forests in tropical countries that have lost most of their original forests, showing land area, original and current natural forest area and change in forest area. Data derived from the United Nations Food and Agriculture Organization (FAO), United Nations Environment Programme, World Conservation Monitoring Centre (WCMC) and World Resources Institute (WRI). Countries are arranged (alphabetically) according to positive or negative annual percentage change in forest area ('total forest').

		Original forest area (000 ha) (% of land area)	*Current natural forest area (000 ha) (% of original forest area)*		*Mean annual % change in forest area*	
Country	*Land area (000 ha)*		*WRI (2000)*	*FAO (2005) primary forest*	*'Natural forest' – WRI (1990–2000)*	*'Total forest' – FAO (2000–05)*
Benin	11 262	1802 (16.0)	2538 (140.8)	na	–2.2	–2.5
Burundi	2783	1280 (46.0)	2538 (1.6)	0 (0.0)	–8.9	–5.2
Comoros	186	112 (50.0)	6 (5.4)	0 (0.0)	–4.1	–7.4
Ghana	23 854	15 744 (66.0)	6259 (39.8)	353 (2.2)	–1.6	–2
Honduras	11 209	11 209 (100.0)	5335 (47.6)	1512	–1.1	–3.1
Mauritania	102 552	0	293 (na)	na	–3	–3.4
Nigeria	92 377	41 570 (45.0)	12 824 (30.8)	326 (0.8)	–2.5	–3.3
Philippines	30 000	28 500 (95.0)	5036 (17.7)	829 (2.9)	–1.9	–2.1
Togo	5679	1874 (33.0)	472 (25.2)	0 (0.0)	–3.1	–4.5
Uganda	24 124	16 873 (70.0)	4147 (24.6)	na	–1.8	–2.2
Cape Verde	403	na	0	na	na	0.4
Costa Rica	5110	5008 (98.0)	1790 (35.7)	180	–1.3	0.1
Côte d'Ivoire	32 246	na	na	625	na	0.1
Cuba	11 086	9977 (90.0)	1867 (18.7)	na	0.1	2.2
Gambia	1130	441 (39.0)	479 (108.6)	na	na	0.4
Palau	46	na	na	na	na	0.4
Rwanda	2634	948 (36.0)	46 (4.9)	0 (0.0)	–7.8	6.9
St. Vincent and Grenadines	39	17 (44.0)	6 (35.3)	na	–1.6	0.8
Cape Verde	403 na		0	na	na	0.4

na, not available.

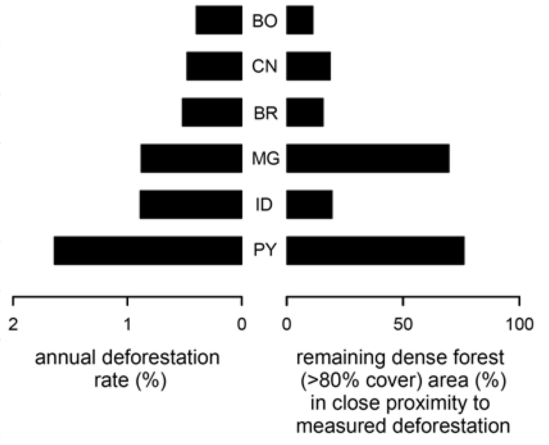


Figure 1.7 Deforestation rates and remaining forest area for countries with a clearing rate of greater than 0.4% per year. Country codes: BO, Bolivia; BR, Brazil; CN, People's Republic of China; ID, Indonesia; MA, Madagascar; PY, Paraguay. (Data derived from M.C. Hansen and DeFries 2004.)

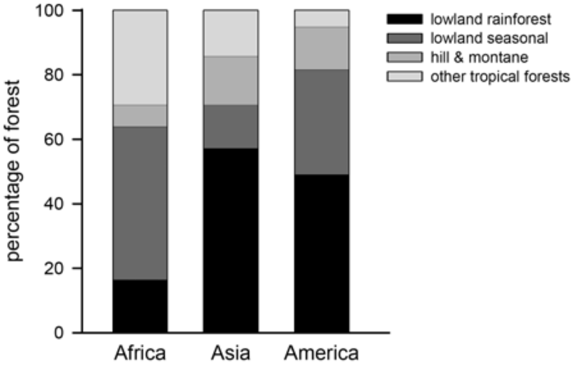


Figure 1.8 Percentage occurrence of different forest types across different regions. (Data derived from Whitmore 1997.)

human activities continue to threaten these vulnerable forests (Ohsawa 1995; IUCN 2000).

Eighty-five per cent of global forest loss occurs in tropical rain forests (Whitmore 1997). However, the tropics also contain seasonal, dry or monsoonal deciduous forests. These generally lie below 1000 m elevation in regions such as Central America, Madagascar and Asia (Thailand) (Ruangpanit 1995; W.F. Laurance 1999), and constitute 33% of the existing tropical forests in the world (Whitmore 1997). Owing to their proximity to human habitation, seasonal forests also suffer a similar fate as lowland rain forests. In fact, seasonal forests

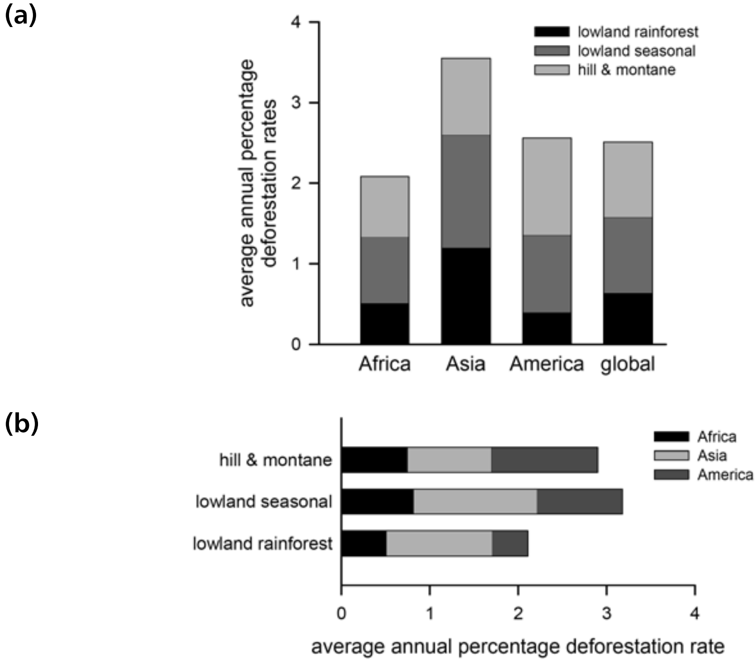


Figure 1.9 Average annual deforestation rates of different forest types at regional (a) and global scales (b), with lowland seasonal forests being lost at the highest rate globally. (Data derived from Whitmore 1997.)

are often grouped, for convenience, with rain forests, and are thus included in some of the regional deforestation calculations (e.g. Achard *et al.* 2002). Indeed, it is estimated that seasonal forests are being lost at the highest rate of any forest type (Figure 1.9) (Whitmore 1997). In some regions, such as Central America and Madagascar, more than 96% of these forests have already been destroyed (Krammer 1997; A. P. Smith 1997; W.F. Laurance 1999).

1.1.2 Mangrove loss

Mangrove forests (growing in saline coastal environments) represent another unique tropical ecosystem. Mangroves are juxtaposed between land and sea and found within 25° north and south of the equator, covering approximately 8% of the world's coastline in 112 countries (Figures 1.10 and 1.11) (Adeel and Pomeroy 2002). In addition to direct overharvesting of trees, mangroves face threats from pollution, siltation, coastal development, aquaculture development and boating and shipping (Adeel and Pomeroy 2002). Traditionally, mangroves have been undervalued and largely considered to be useless swamps or wasteland (Liow 2000; Adeel and Pomeroy 2002). However, as with other forest types, mangroves support extensive biodiversity and contribute to varied ecosystem functions. For example, the presence of mangroves may enhance fish, shrimp

Figure 1.10 A tropical mangrove swamp in Singapore. (Photo by Hugh Tan.)

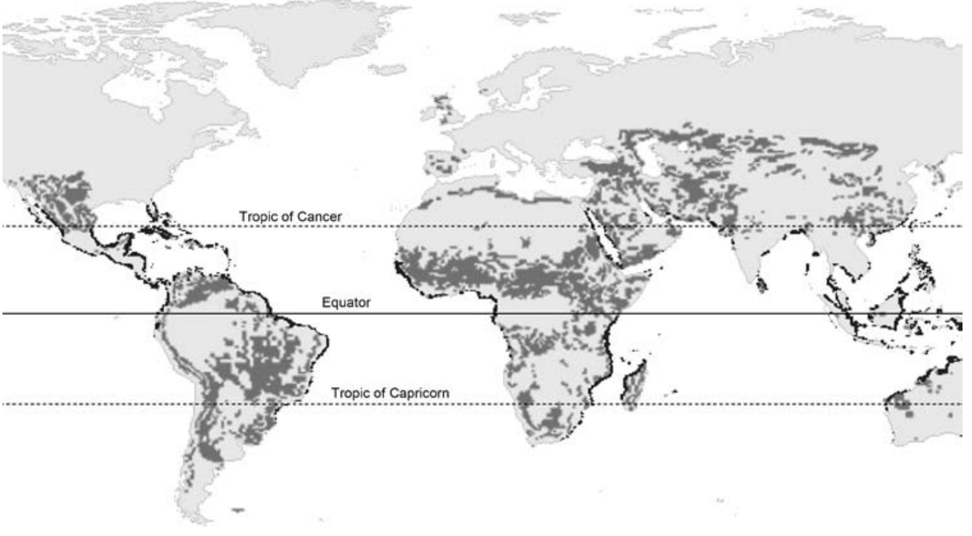


Figure 1.11 Global distribution of mangroves (black) and tropical savannas and grassland (dark grey). [After United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) online 2007. With permission.]

and prawn catches (Baran and Hambrey 1998), producing an estimated US$66 to almost US$3000 of fisheries-related annual income from 1 ha of mangrove (Baran and Hambrey 1998). Although this estimate may be inflated because it does not include fisheries yield exclusively reliant on mangroves, it does show that human livelihoods can depend on this habitat type. Because of these indirect benefits to human well-being, conversion of mangroves for aquaculture may generate around 70% less revenue from the overall system than the pristine state (Balmford *et al.* 2002). Despite their environmental and economic benefits, mangroves are currently being lost at a rate of 2–8% per year. Between 4% and over 60% of the original mangrove cover has been lost in different tropical regions (Figure 1.12) (Valiela *et al.* 2001; Adeel and Pomeroy 2002).

In Southeast Asia, Singapore epitomizes mangrove destruction and conversion: mangrove forest cover amounted to 6334 ha (63% of original) in 1953, but by 1993 this had declined only 6.5% (Hilton and Manning 1995), with a further reduction to 4% projected by 2030 (Figure 1.13). The primary driver of this massive destruction of mangrove forests in Singapore has been coastal

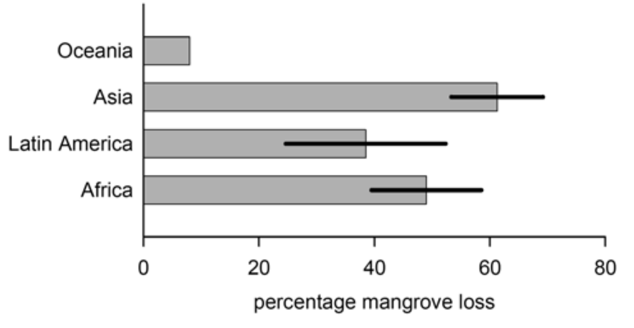


Figure 1.12 Percentage of original mangrove forest loss in different regions. Error bars represent standard error and are missing from Oceania because it is represented only by Papua New Guinea. (Data derived from Adeel and Pomeroy 2002.)

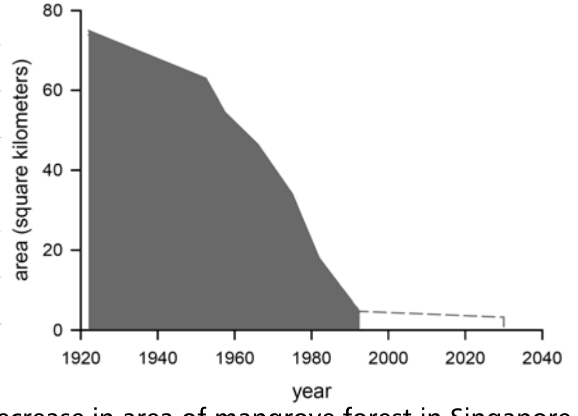


Figure 1.13 Decrease in area of mangrove forest in Singapore, with projected estimates up to 2030. (After Hilton and Manning 1995. Copyright, Cambridge University Press.)

development associated with urban expansion and industrialization (Hilton and Manning 1995). The mangrove loss in Singapore has also resulted in biotic losses. For example, at least four mangrove plant species (e.g. *Barringtonia conoidea*) have been extirpated from the island (Liow 2000). On a positive note, mangrove cover in the Central American nation of Costa Rica increased by 6% between 1983 and 1990 as a result of regeneration and plantations (Adeel and Pomeroy 2002).

1.1.3 Loss of tropical savannas

Tropical savannas or grasslands are associated with a highly seasonal climate of a prolonged dry and a shorter wet season (Figures 1.11 and 1.14). This type of extreme climate is expected to produce some form of forest or woodland, but soil conditions (e.g. low soil fertility) or disturbance prevent the establishment of dominant tree cover in these areas. Indeed, savannas are shaped (and now managed) by fire and grazing pressures of mega-herbivores. The African savannas are the best known, covering much of central and southern Africa. However, savannas also cover large areas of Central and South America (pampas), western India and northern Australia (Figure 1.11). Savannas are characterized by continuous cover of perennial (a plant persisting for several years) grasses, often reaching 3 m at maturity. Savannas may have an open canopy of drought-, fire- or browse-resistant trees. The dominant layer of these trees distinguishes the type of savannah, for example acacia savannah and pine savannah. Both tree and grass species in savannas have underground root systems that allow them to survive prolonged periods of drought and/or fire. There are other adaptations to resist the stress imposed by droughts, e.g. baobab trees (*Adansonia digitata*; Figure 1.15) in Africa have evolved huge trunks to draw out and store moisture during

Figure 1.14 A tropical savannah in Kenya. (Photo by Chuck Bargeron, University of Georgia, www.forestryimages.org.)

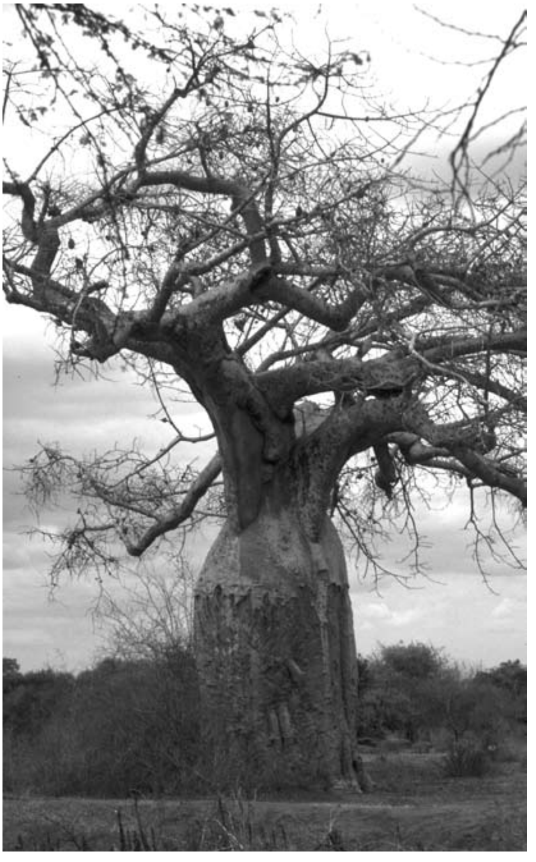


Figure 1.15 Baobab trees (*Adansonia digitata*) in Kenya. [Photo by Robert L. Anderson, United States Department of Agriculture (USDA) Forest Service, forestryimages.org.]

drought, perennial grasses die back and trees lose their leaves to reduce water loss through transpiration during dry seasons.

The world's greatest diversity (> 40 species) of ungulates (hoofed mammals) is found in the savannas of Africa and includes wildebeest (*Connochaetes taurinus*), oryx (*Oryx gazella*) and zebra (*Equus* spp.). These species-rich communities of large-bodied mammals attract a diverse set of carnivores such as lions (*Panthera leo*), cheetahs (*Acinonyx jubatus*), jackals (*Canis adustus*) and hyenas (*Crocuta crocuta*). Termites are also abundant in tropical savannas; they feed on decomposing animal and plant remains and thus are important for maintaining soil fertility. In fact, trees growing nearer to termite mounds in western Zimbabwe have higher nutrients and are preferred as browse by elephants (*Loxodonta africana*) (Holdo and McDowell 2004). Additionally, termite nesting mounds provide shelter for other animals and are the sole food for anteaters (*Myrmecophaga* spp.) and pangolins (*Manis* spp.).

The Cerrado region of Brazil exemplifies the importance of, and threats to, the savannas. These savannas cover 21% of Brazil and are exceptionally rich in endemic species (Figure 1.16) (Klink and Machado 2005). Despite this richness, 55% of the 2 million km^2 of forest cover in the Cerrado has been transformed or cleared for human use, with the main threats being soil erosion, uncontrolled fire and the spread of exotic grasses (Klink and Machado 2005). An issue of particular conservation concern is that 20% of threatened endemic species do not occur in any of the region's protected areas (Klink and Machado 2005). A similar predicament is unfolding in the savannas of the Serengeti National Park in Tanzania (Sinclair *et al.* 2002). Some 5% of the grasslands in this region are each year converted for human use, such as agriculture. Compared with native savannah, only 28% of all bird species, and 50% of insectivorous and granivorous species, are found in agricultural areas (Sinclair *et al.* 2002). That study suggested that continuing human encroachment in this ecosystem would negatively affect bird species and perhaps some larger vertebrate species, such as lions and cheetahs. Worldwide, 50% of the tropical and subtropical savannas have already been sequestered for use by humans, with further projected losses of about 20% by the year 2050 (Figure 1.17) (Millennium Ecosystem Assessment 2005).

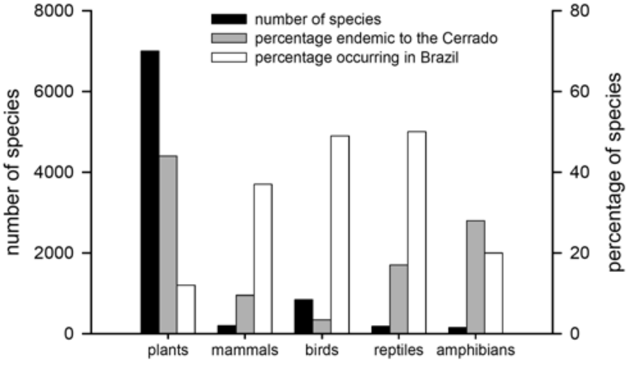


Figure 1.16 Number of species with per cent endemism and proportion of estimated species richness in the savannas of Brazil. (Data derived from Klink and Machado 2005.)

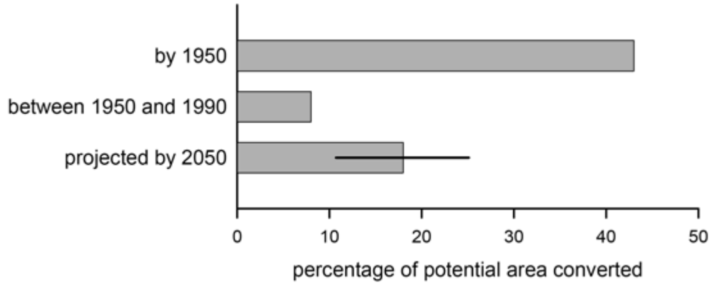


Figure 1.17 Loss of savannas over the past century and projected conversion by 2050. Bars represent medium certainty, and the error bar represents a range of values from four different Millennium Ecosystem Assessment scenarios. (After Millennium Ecosystem Assessment 2005. With permission.)

1.1.4 Loss of limestone karsts

Limestone karsts are sedimentary rock outcrops composed primarily of calcium carbonate (Figure 1.18). They were formed millions of years ago by calcium-secreting marine organisms (e.g. corals) and were subsequently lifted above the sea level by tectonic movements. The complex terrain of karsts translates into high species diversity, because many of the species can be site-endemic owing to a high degree of isolation among the karsts. For example, 21% of 1216 karst-associated plant species are endemic to Peninsular Malaysia, with 11% of these being site endemics (Chin 1977). Similarly, 80% of Malaysian landsnails live on karsts, with many of them occurring only on individual karsts (Clements *et al.* 2006). Karsts should have high conservation priority because they are home to 143 globally threatened species, and 18 karst-dominated species have already been lost from Peninsular Malaysia due to habitat loss (Kiew 1991; Clements *et al.* 2006). In addition, karsts are valuable to humanity because of their rainwater storage abilities and thus the role in maintaining the hydrological integrity of catchments. They also are magnets for tourists – karsts in Sarawak (Malaysia) generate at least US$80 000 annually in tourism-related revenues. Despite this, tropical karsts are currently being quarried heavily for limestone to be used in over 100 commercial products such as cement. More than 400 million tonnes

(a)

(b)

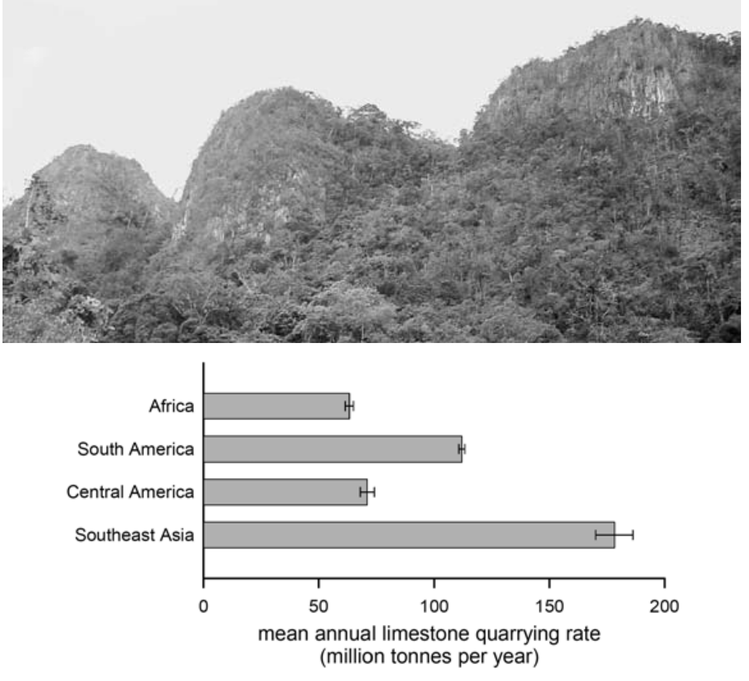


Figure 1.18 (a) Pristine tower karsts in Sarawak, East Malaysia, and (b) the mean (± standard error) annual limestone quarrying rates of four major tropical areas (1999–2003). (After Clements *et al.* 2006, Copyright, American Institute of Biological Sciences. Photo by Reuben Clements.)

of limestone were quarried from karsts in the tropics over a period of 5 years (Figure 1.18). Clearly there is a need for more conservation attention to this imperilled ecosystem.

In addition to loss, fragmentation and degradation of once pristine areas, tropical habitats are affected by drivers such as climate change, invasive species, overexploitation (e.g. hunting) and pollution (Figure 1.19) (Millennium Ecosystem Assessment 2005). These elements will be covered in later sections and chapters.

1.2 Drivers of habitat loss

Direct causes of deforestation (and loss of other habitats) are multifarious, and include slash-and-burn clearing associated with swidden agriculture, selective logging, cattle ranching, plantations, permanent agriculture, fuel wood collection and transmigration. These drivers can act individually or in concert. In the tropics, the main proximate drivers of deforestation are agriculture, followed by timber extraction and infrastructure (urban) expansion (Geist and Lambin 2002). However, the precise causes of deforestation are underpinned by complex and geographically variable factors. For instance, some governments have little choice but to sell forests as logging concessions to alleviate foreign debt (Bawa and Dayanandan 1997). Below we discuss in some detail the various drivers of habitat loss in the tropics.

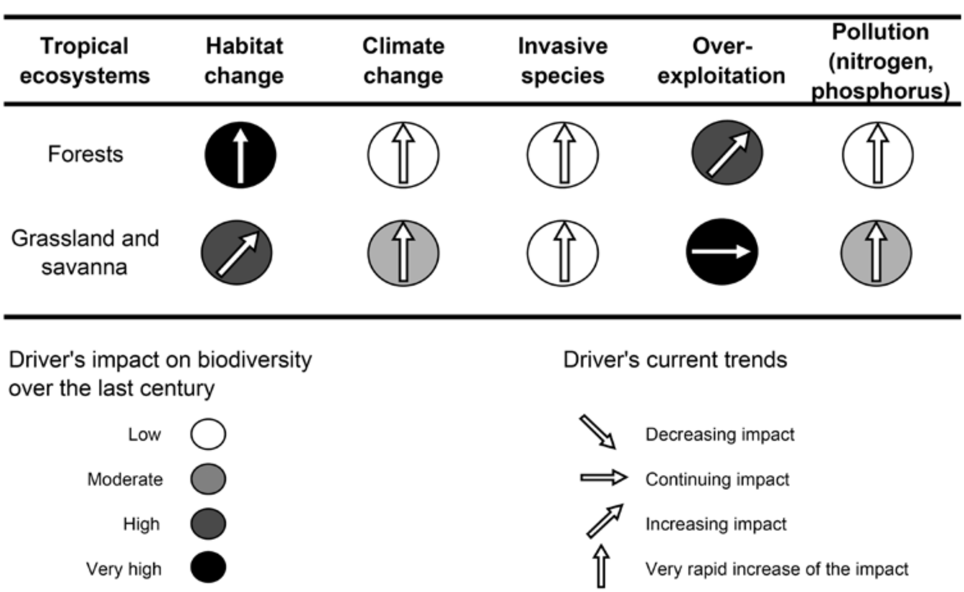


Figure 1.19 Factors that affect tropical habitats and their current trends. (After Millennium Ecosystem Assessment 2005. With permission.)

1.2.1 Human population pressure

The increasing demand for, and consumption of, natural resources by humans shows no sign of abating. Rapid economic development, population expansion and poverty are key drivers of land conversion (Giri *et al.* 2003; Jha and Bawa 2006). Demographic growth is particularly steep in tropical countries, where the size of the human population has increased by 3.1 billion between 1950 and 2000, and is projected to grow by another 2 billion before 2030 (United Nations 2004). Within the next 100 years, as many as 11 billion people may inhabit the planet, a number that will be difficult to sustain (Palmer *et al.* 2004). Urbanization will greatly expand in the future, with expectations that more than half of the world's total human population will be living in cities by 2030 (see Figure 1.6) (Palmer *et al.* 2004). Expanding human populations, and their specific actions (e.g. land conversion), exert substantial pressure on natural resources and native biodiversity (Cardillo *et al.* 2004). Additional, poor policy choices can also exacerbate environmental destruction (Jha and Bawa 2006).

It would be immeasurably informative, from both a scientific and management perspective, if we could hypothetically excise a representative tropical country, allow it to fulfil its economic potential, and document the consequent loss of natural habitats and biodiversity, all within a greatly accelerated time frame. It is both depressing and fortunate that the Southeast Asian island nation of Singapore provides exactly such an ecological worst case scenario for the tropics. Singapore has experienced an exponential population growth from around 150 subsistence-economy villagers around 1819 to 4 million people in 2001 (Corlett 1992; World Bank 2003). In particular, within the past few decades, Singapore has transformed itself from a Third World country of squatters and slums to a developed metropolis of economic prosperity and thus has been widely regarded, by the regional developing countries, as the ideal economic model. However, the success of Singapore came at a hefty price, one that was unfortunately paid for most particularly with its biodiversity (Brook *et al.* 2003a). The island has suffered massive deforestation, initially from the cultivation of short-term cash crops (e.g. gambier: *Uncaria gambir*, rubber), and subsequently from urbanization and industrialization (Corlett 1992). With this destruction of habitats (rain forest, swamp forest and mangroves) has come the extirpation of at least a third of the island's known biodiversity. Similar environmental scenarios are now unfolding in other tropical countries, often at much greater geographic scales (Jepson *et al.* 2001).

As the human population of tropical countries continues to grow, enormous pressures will be placed on their natural resources (World Bank 2003). The current trend in the tropics suggests that forest loss will likely increase in tandem with human population density, and in some cases due to economic expansion as well (Figure 1.20 for all tropical countries). The point to note, however, is that the pressure of dense human populations represents only one of the factors in habitat loss because, even in areas with relatively few human residents in the tropics, there can be widespread loss of natural forests (Whitmore 1997).

A burgeoning human population, even with an increasing concentration of people in urban areas, means more mouths to feed, and agriculture is the main factor

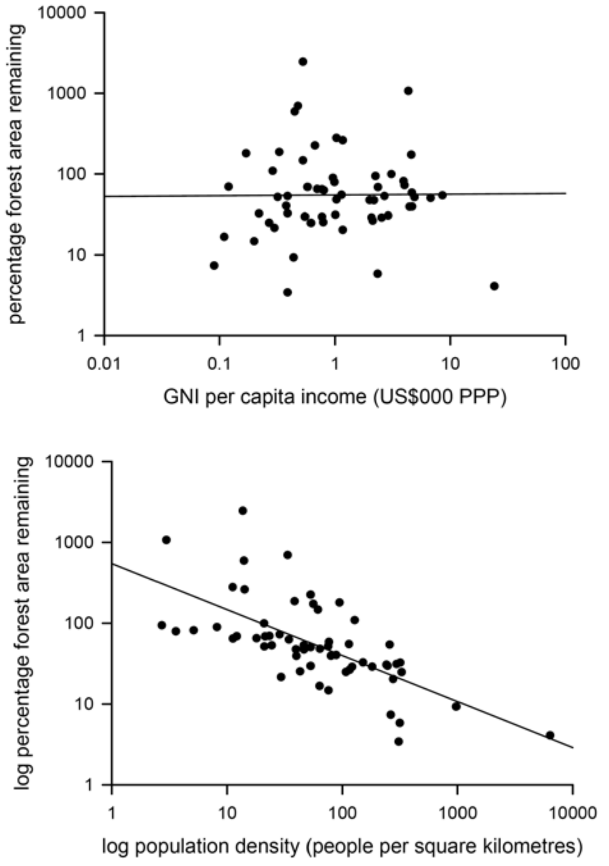


Figure 1.20 Socioeconomic correlates of percentage forest loss. The proportion of forest area remaining in tropical countries did not correlate with (a) gross national income (GNI) but correlated negatively with (b) population density. Percentage of forest area remaining is defined as the proportion of current total forest area over estimated forest cover about 8000 years ago assuming current climatic conditions. (Data derived from www.earthtrends.wri.org.)

in land conversion in the tropics (Figure 1.21), with its estimated contribution to annual tropical forest losses being as high as 90% (Hardter *et al.* 1997; Achard *et al.* 2002). In Asia, 100 million ha of land was converted to cropland between 1880 and 1980. Over these 100 years, the area of land converted to agriculture expanded by 86% in this region (Flint 1994; Richards and Flint 1994), largely at the expense of its forests (Flint 1994; Bawa and Dayanandan 1997) (Figure 1.22). Production of soya bean (*Glycine max*) has increased 100-fold since 1961 in Argentina and Brazil, largely for export to China (Donald 2004). This has resulted in a severe shrinking of Cerrado grasslands (Donald 2004).

Globally, over the last three decades, agricultural areas have doubled from

Figure 1.21 Agriculture in the tropics. (Photo by Cagan Sekercioglu, naturalphotos.com.)

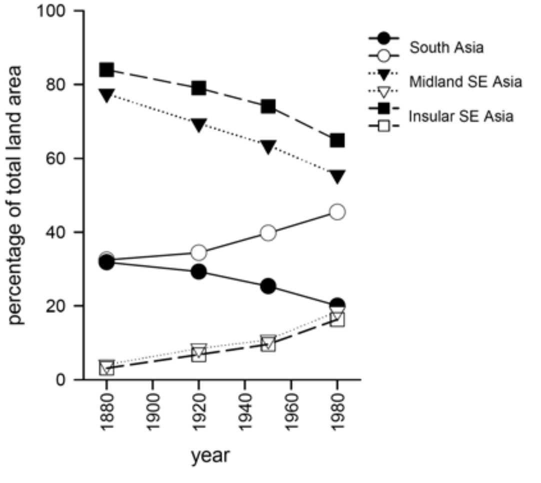


Figure 1.22 Change in cultivated area and forest cover of South and Southeast Asian countries (filled symbols: cultivated areas; unfilled symbols: forest cover). (After Flint 1994. Copyright, Elsevier.)

50 million ha to 100 million ha (Niesten *et al.* 2004), and now cover a quarter of earth's land surface (Millennium Ecosystem Assessment 2005). By 2030, it is predicted that an additional 120 million ha of agricultural land will be needed by developing countries to support their increased populations (M. Jenkins 2003); therefore, land clearing for agriculture is almost certain to continue at a rapid

pace. In addition, in many areas of the tropics factors such as low soil fertility and high levels of erosion mean that land conditions are not particularly conducive to sustainable agriculture, thus promoting a cycle of forest destruction. Farmers have to burn forest vegetation to release nutrients that enhance soil fertility and, as a result of the region's characteristically high rainfall, these nutrients are usually washed away rapidly, making the soil less fertile; in as little as 3 years the ground is no longer capable of supporting crops (Härdter *et al.* 1997). Farmers are then forced, because of the reduced soil fertility, to look for new forested areas to clear and burn.

Agricultural plantations (large-scale, export-oriented monocropping) are also on the rise in the tropics. Areas under plantation doubled from 4% to 8% between the 1970s and 1984 (Hartemink 2005) – a trend that has most likely continued since (no distinction is made between perennial plantations and smallholdings in data obtained by FAO thereafter). For instance, the area under oil palm (*Elaeis guineenis*) cultivation increased from 150 000 ha in the 1970s to over 3 million ha in 1998 (Hartemink 2005). Similar trends have been found for cocoa plantations in the Ivory Coast and for sugar cane (*Saccharum officinarum*) plantations in India and Brazil. In Brazil soya bean (*Glycine* sp.) cultivation has increased by 13 million ha in the past 30 years, mostly at the expense of its wooded savannas (Niesten *et al.* 2004); these agricultural plantations contribute substantially to the gross national product (GNP). Forest conversion to cropland in the Brazilian Amazon is directly correlated with soya bean prices, indicating that high crop prices in the international market can promote deforestation (D.C. Morton *et al.* 2006). In the 1980s, exports from plantations contributed 22% to the GNP of the Ivory Coast, and rubber accounted for 10% of GNP exports in Malaysia (Hartemink 2005). However, these plantations can release pollutants, cause soil erosion and declining soil fertility and can be poor in sequestering carbon and promoting biodiversity values (Hartemink 2005).

Cultivation of coca and poppies for the illicit drug trade may be the cause of almost half of the deforestation in neotropical countries (Aldhous 2006). Biologists and governmental officials trying to prevent deforestation as a result of illicit drug demand (mostly in the USA) are threatened with violence (Aldhous 2006).

Massive resettlement programmes, such as those in Indonesia, Thailand and the Philippines, Burundi and Rwanda, also facilitate deforestation (R.L. Bryant *et al.* 1993; www.fao.org). Fuel wood is thought to constitute 85% of total energy consumption in West Africa, and this has resulted in heavy deforestation and occasional shortages of such wood, particularly in Niger, Nigeria and Togo (www.fao.org). Civil war in tropical countries has compromised conservation because illegal logging money has been used to fund conflict (Talbott and Brown 1998; Draulans and van Krunkelsven 2002), although war can sometimes facilitate forest regeneration, for instance by deterring commercial operations (Hecht *et al.* 2006). Last, but not least, the liberal granting of forestry concessions, largely though cronyism and corruption, does not bode well for the remaining tropical forests (Geist and Lambin 2002; see Chapter 10).

1.2.2 Perverse subsidies

Some government actions inadvertently promote poor land use practices. Subsidies designed to promote agricultural production also facilitate land clearing (Barbier 1993; A.N. James *et al.* 1999). These subsidies are called 'perverse' because, over the long term, they adversely affect the economy and the environment (Myers 1998). For example, worldwide, citizens pay US$950–1450 billion annually to subsidise fisheries and the timber and oil palm industries (Myers 1998; van Beers and de Moor 1999). The largest amount of money (US$345 billion/year) goes to agriculture and fisheries (van Beers and van den Bergh 2001). Global ocean fisheries cost US$100 billion a year, of which only US$80 billion is recovered through sales – the shortfall is made up by government subsidies (Myers 1998). This has resulted in the depletion of fisheries stocks to unsustainable levels, bankruptcy of fishing businesses and a high unemployment rate in fisheries communities. Despite this problem, the European Union (EU) has been increasing subsidies to its fishing fleets in West Africa, thus artificially inflating profitability against the backdrop of declining fishing stocks (Brashares *et al.* 2004). In Brazil, the depletion of soils, forests and fisheries as a result of perverse subsidies to agriculture has depressed its economic growth potential by up to 30% (Myers 1998).

Coffee cultivation provides a useful illustration of the nature of perverse subsidies in agriculture. During the 1990s, Asian governments with the support of the International Development Bank promoted intensive coffee cultivation in countries such as Indonesia and Vietnam, elevating Indonesia to the world's fourth largest coffee exporter and the second largest producer of coffee after Vietnam. Unfortunately, this short-term economic gain resulted in massive forest conversion, and eventually proved to be economically unsustainable due to overproduction and the subsequent collapse of world prices (O'Brien and Kinnaird 2003). Despite it being clear that coffee production is not economically attractive in many situations and that it is detrimental to biodiversity, the Indonesian government plans to expand coffee production further. O'Brien and Kinnaird (2003) recommended that the adoption of coffee cultivation be strongly discouraged in protected areas and that strident attempts should be made to curtail deforestation for this type of cultivation. Certainly, organizations such as the International Coffee Organization need to play a bigger role in promoting a balance between coffee production and biodiversity needs.

In addition to agriculture, governmental financing of road construction can act as an indirect subsidy by facilitating logging (Flint 1994; van Beers and van den Bergh 2001) and can lead to an increase in the hunting of wild animals by providing easier access to the forests (see Chapter 6). Further, underpricing of timber and subsidies of private harvesting (e.g. low logging fees and taxes) promote deforestation (Barbier 1993). For example, in the Philippines, timber revenues collected by the government during the late 1980s were six times lower than the prevailing market value (US$39 versus US$250 million; Barbier 1993). More than 46% of the money generated by timber concessions in Malaysia and Indonesia since the early 1990s remains uncollected (www.fao.org), suggesting that logging does not benefit the local people economically.

1.2.3 Commercial logging

Commercial logging is also another common direct driver of deforestation, especially in the tropics (Geist and Lambin 2002). Trees are felled for sale as timber, timber products (e.g. woodchips), or pulp. Between 1981 and 1990, 5.6 million ha of tropical forest was logged for timber (Whitmore 1997). Such logging activities predominantly occur in the primary forests (Figure 1.23) (Whitmore 1997). Forestry industries account for 3% of the world's gross economic output, or approximately US$330 billion annually (Sizer and Plouvier 2000). The annual total worldwide consumption of wood is around 3 billion cubic metres, with about half of that consumed as firewood. The Asia-Pacific region now drives log exports in the tropics, encompassing 67% of the total volume (Sizer and Plouvier 2000) (Figure 1.24).

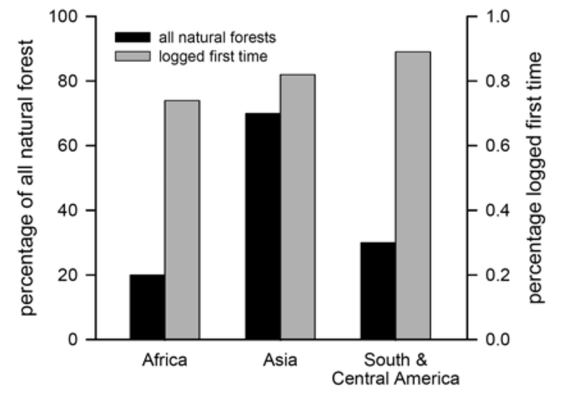


Figure 1.23 Proportion of remaining natural forest areas and percentage of primary forests area logged for the first time in those forests. (Data derived from Whitmore 1997.)

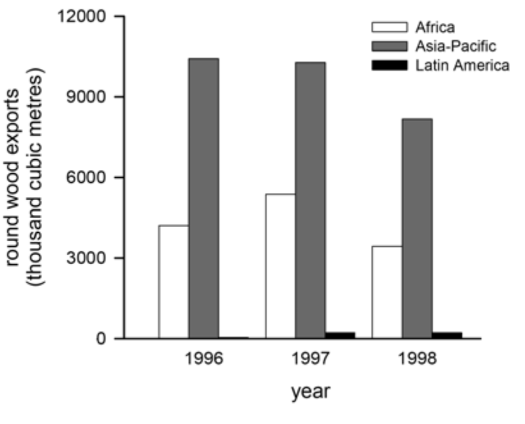


Figure 1.24 Log exports of round wood from different regions from 1996 to 1998. (Data derived from Sizer and Plouvier 2000.)

Over the past few decades, Indonesia, Brazil and Malaysia have logged more than half of the world's commercially viable tropical timber, with Thailand and India also in the top five producers [ITTO (International Tropical Timber Organization) 2003] (Figure 1.25). The high level of commercial logging is also of concern in countries with currently vast intact tropical forests, such as Gabon, Cameroon and Papua New Guinea (Figure 1.26), as there is little possibility

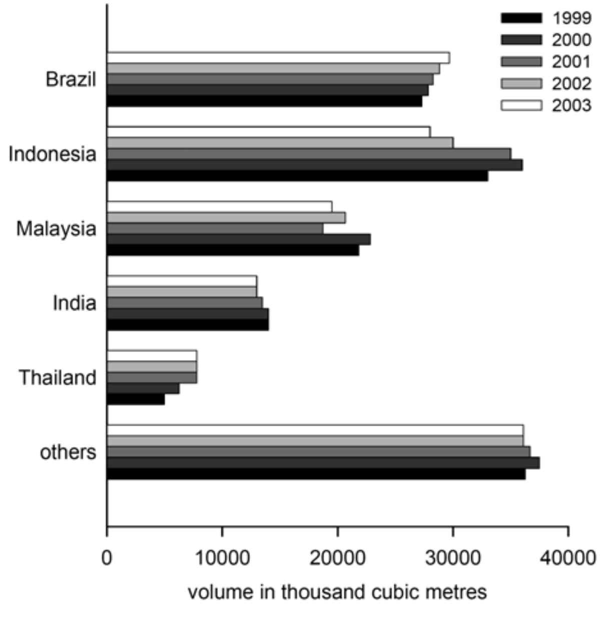


Figure 1.25 Tropical timber producers from 1999 to 2003. (Data derived from International Tropical Timber Organisation 2003.)

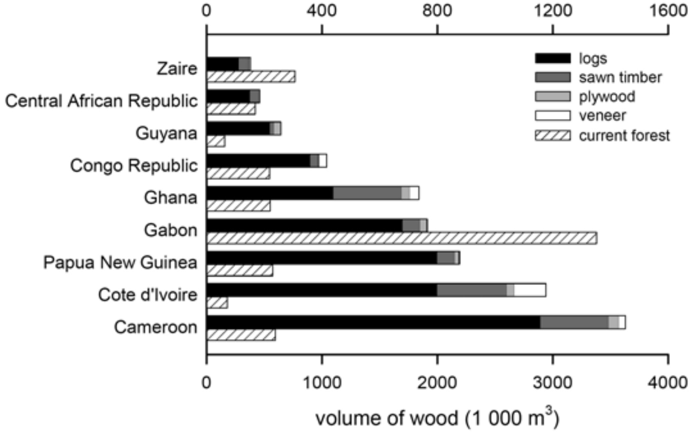


Figure 1.26 Production of various commercial logging materials from the top nine countries and their remaining natural forest area. (Data derived from Sizer and Plouvier 2000.)

of further protection of forests in these countries. In many of these countries, timber harvesting occurs in the absence of any management plan that might seek sustainability [Centre for International Forestry Research (CIFOR) 2004].

Japan, South Korea and the People's Republic of China are the main importers of tropical timber products (Sizer and Plouvier 2000). Forest products exported by developing countries are usually subject to low export duties, particularly on unprocessed logs (Barbier 1993). Trade liberation, through the removal of export restrictions, may increase log exports (up to fourfold in the Philippines) and thus cause a further acceleration in deforestation (Barbier 1993). In addition, current bans on commercial logging within India and the People's Republic of China promote higher demand for the supply of tropical wood from other countries (www.birdlife.net). Between 1997 and 2002, China's forest product imports soared by 75%, from US$6 to 11 billion (Sun *et al.* 2004). Over 70% of China's forest products are supplied by countries in the Asia Pacific region (Katsigris *et al.* 2004). Many supplying countries are rife with unsustainable harvesting, illegal logging and concomitant negative impacts on human livelihoods. Greater attention by governments, market leaders and international organizations is needed to address the problems that tropical timber export creates in the source country (Katsigris *et al.* 2004).

Moreover, deforestation is actually encouraged by governments in the tropics because of high international demand for tropical wood and wood products (Kummer and Turner 1994), and examples of sustainable natural forest use in the tropics are difficult to find (Bowles *et al.* 1998; Putz *et al.* 2000; W.F. Laurance *et al.* 2001a). Unsustainable logging remains 20–450% more profitable, at least over the short term, than sustainable practices such as fruit collection and meat production (Bowles *et al.* 1998; but see Balmford *et al.* 2002). Logging in many tropical countries is still done by clear-felling (Barbier 1993), yet even 'selective logging' can be very wasteful, resulting in the felling of an average of 25 non-commercial trees for every commercial-quality tree extracted (Myers 1991) and 40–50% of the canopy cover being destroyed (Cochrane 2003). Further, logging concessions are typically awarded for short durations (5–25 years) that tend to promote logging in new areas (Barbier 1993).

Old-growth forests are also being targeted and depleted across the tropics (Whitmore 1997). The highest percentage of logging in neotropical old-growth forests occurred from 1981 to 1990 (see Figure 1.23) (Whitmore 1997), and in many areas of Southeast Asia old-growth forests are being logged to oblivion (Barbier 1993; Whitmore 1997). Clearly, stiffer guidelines are needed to regulate, and perhaps curtail, mass tropical timber production and export. These might include mandatory timber certifications, better economic incentives to encourage sustainable harvesting, substantial reviews of export duties and laws and a more widespread promotion and education of environmental issues (see Chapter 10). Furthermore, because they are often the only institutions in remote areas, logging companies can themselves assist in environmental protection, although there are instances of officials wanting to stop illegal logging being intimidated by arson, attempts at bribery and murder (Jepson *et al.* 2001; Aldhous 2006).

Agriculture and commercial logging may have differing impacts on deforestation rates in the tropics; however, in many areas, both logging and agriculture act in concert to exacerbate deforestation (Kummer and Turner 1994). As described earlier, by creating roads, logging operations enhance physical access to forests. This greater access increases the likelihood of invasion by humans (e.g. hunters, farmers and miners) and exotic organisms associated with humans (e.g. rats, dogs, cats), and is a cause of considerable concern for the long-term prospects of tropical biodiversity (W.F. Laurance *et al.* 2001a).

1.2.4 Weak governance

Anaemic national institutions and poor enforcement of legislation remain a major hindrance to curtailing tropical deforestation (W.F. Laurance 1999). Liberal granting of forest concessions, non-existent or poor forestry practices, weak governance structures and political corruption all work to maintain high deforestation rates in developing countries (R.L. Bryant *et al.* 1993; Geist and Lambin 2002; R. J. Smith *et al.* 2003). Illegal logging (timber harvesting, transportation and trade in violation of national laws) and encroachment into nature reserves remain a problem across the tropics (www.fao.org/forestry; T. Whitten *et al.* 2001; DeFries *et al.* 2005). For example, it is reported that illegal and possibly unsustainable logging remains rampant in Indonesia with the implicit backing of politicians, businesses and the military (Kinnaird and O'Brien 2001; T. Whitten *et al.* 2001; Stibig and Malingreau 2003; see Chapter 10). Certain people implicated in illegal logging continue to retain prominent political positions (T. Whitten *et al.* 2001). Forest policies are not sufficiently well developed to protect the remaining forests adequately and to stem the growth of industries based on forest exploitation. For instance, Indonesia's paper and pulp industry has grown sevenfold since the 1980s, with a similar expansion in the production of plywood. Further, the oil palm plantation areas and resettlement plans for some native people have placed even greater pressure on these forests (Stibig and Malingreau 2003).

Sadly, the events occurring in Indonesia are not anomalous – they in fact epitomize disturbing actions across most of the tropics. Illegal logging costs the timber industry up to US$15 billion annually (S. Johnson 2003). Seneca Creek Associates and Wood Resources International (2004) estimate that up to 10% of forestry trade worldwide is based on illicit timber products. This rampant illegal activity in the tropics makes up between 20% and 90% of forest production and trade in some tropical countries (Figure 1.27) (Seneca Creek Associates and Wood Resources International 2004), with corruption seeming to facilitate logging (Figure 1.28). The construction of roads in many tropical areas further enables illegal logging in already overlogged areas (Barbier 1993).

In many tropical nations, forests are managed by government departments, whose main interest seems to be to increase commercial logging and the export of timber products without any consideration for the conservation of biodiversity (Byron and Waugh 1988). Furthermore, these departments remain understaffed and heavily politically influenced (Barbier 1993), so that logging companies identified as having poor environmental practices (e.g. promoting forest fires) can continue to conduct unscrutinized 'business as usual' (T. Whitten *et al.* 2001). Rampant corruption and illegal activities hinder proper management of

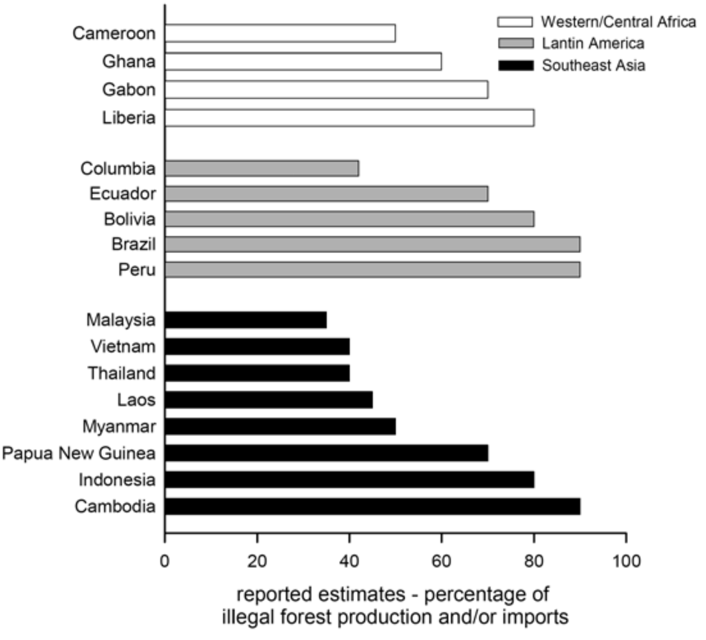


Figure 1.27 Proportion of illegal production of wood products and/or imports of different countries across various tropical regions. (Data derived from Seneca Creek Associates and Wood Resources International 2004.)

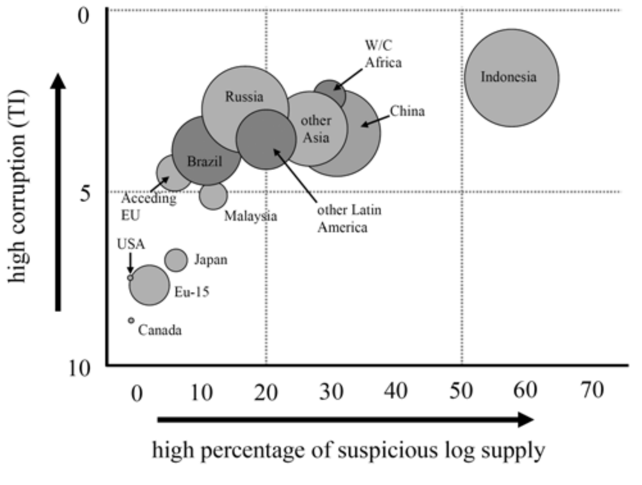


Figure 1.28 Relationship of estimates of suspicious log supply and the corruption index of selected countries. (After Seneca Creek Associates and Wood Resources International 2004. With permission.)

forests in many parts of the tropics (Kummer and Turner 1994; see Chapter 10). For example, corruption has been a major contributing factor to the heavy deforestation of the Philippines (Kummer and Turner 1994), and this is very likely to also be a major factor in furthering deforestation in other tropical countries. The few but well-publicized struggles by some native groups (e.g. Penan of Sarawak) to halt logging have generally been in vain (R.L. Bryant *et al.* 1993).

1.3 Biodiversity hotspots

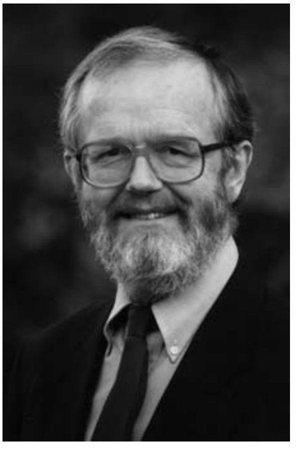
Because there are finite economic and logistical resources available for conservation, wisdom dictates that their value in retaining biodiversity must be maximized. Therefore, it is critical to identify priority areas where conservation needs are the greatest, in order to achieve the most significant payoffs in terms of the global preservation of species and communities. On this basis, Myers (1988) identified 10 terrestrial 'hotspots' where levels of vascular plant endemism were exceptional but which were marred by massive habitat loss and thus should be accorded the highest conservation priority. To these, Myers later added another eight hotspots – these 18 hotspots support 20% of the earth's plant species within just 0.5% of its land surface (Myers 1990).

Critics of the hotspots approach to identifying conservation priorities have argued there are poor complementarities among taxonomic groups, e.g. hotspots for plants may not be hotspots for butterflies (Reid 1998). In 2000, Myers *et al.* (2000; see Spotlight 1: Norman Myers) expanded this paradigm of conservation planning by including, in addition to vascular plants, key vertebrate groups (amphibians, reptiles, birds and mammals) in their analyses. Vascular plants and vertebrate groups were the best candidates for such analyses because the available data on the distribution and conservation status were sufficient to make robust assessments. Myers *et al.*'s (2000) now famous analyses identified 25 terrestrial biodiversity hotspots globally – defined as regions that harbour a high diversity of endemic species from plant and animal taxa and, simultaneously, have been heavily impacted and altered by human activities. The criteria for designating a hotspot were that, out of the 300 000 vascular plant species in the world, at least 0.5% or 1500 vascular plant species should be endemic to it, and that it should have lost at least 70% of its primary vegetation (habitats rich in endemic species). Collectively, these 25 biodiversity hotspots have exceptionally high endemism and harbour some 44% of world's plant species and 35% of its vertebrate species. These hotspot areas collectively have lost 88% of their primary vegetation, thus restricting these endemic species to only 1.4% of the earth's land surface. Sixteen (64%) of these hotspots are in the tropics. The five 'hottest' hotspots (highest levels of endemicity coupled with the greatest threats) are all in the tropics – the tropical Andes, Sundaland, Madagascar, Brazil's Atlantic Forest and the Caribbean. These five together contain 20% of all vascular plant and 16% of vertebrate species, yet cover a mere 0.4% of the earth's land surface.

Myers *et al.* (2000) argued that conservation in these 25 biodiversity hotspots is imperative if we are to counteract the mass extinction crisis that is now unfolding (see Chapter 9). The threat to biodiversity hotspots from humans is

Spotlight 1: Norman Myers

Biography



My graduate education was based on systems ecology and resource economics, with lots of demography, sociology, ethics, forestry, and lengthy etc. thrown in. By the time I had completed my PhD at Berkeley, I was solidly disposed to specialize in being a generalist. I also decided that I was not a team player, and that I would be better off as a lone-wolf consultant in environment and development. I strongly recommend to anybody embarking on a career to find one that keeps their options open. In a former age it was OK to say at age 20 that you wanted to spend the next 50 years being a lawyer or a doctor or something of that sort. But today things are different. Within just another 10 years, the world will have changed out of sight, and you will have changed too, so you might well encounter a need to change horses in mid-career. I actually entered postgraduate school at the advanced age of 35, having been a colonial officer for my first career, a high-school teacher for my second, a professional photographer for my third, a journalist/book writer for my fourth, and, after Berkeley, a consultant. At age 72, I am pondering what I could try for a sixth career.

Major publications

Myers, N. (1976) An expanded approach to the problem of disappearing species. *Science* **193**, 198–202.

Myers, N. (1996) The biodiversity crisis and the future of evolution. *The Environmentalist* **16**, 37–47.

Myers, N. (1998) Lifting the veil on perverse subsidies. *Nature* **392**, 327–328.

Myers, N. and Kent, J. (2003) New consumers: the influence of affluence on the environment. *Proceedings of the National Academy of Sciences of the USA* **100**, 4963–4968.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature* **403**, 853–858.

Questions and answers

Have 'biodiversity hotspots' proven to be a useful concept for applied conservation?

Yes, the biodiversity hotspots thesis has (if I might indulge my immodesty) proved to be an especially useful concept for applied conservation. At any rate, it has attracted funding to the tune of US$850 million from the World Bank, Conservation International, the MacArthur and Moore Foundations and numerous NGOs. For fully two decades before I first formulated the hotspots thesis in the mid-1980s, I had been struck that conservation bodies had been spreading their all-too-inadequate funds in terms of a bit for this species, a bit for that species, and so on, and not really making a big enough impression with any species (for the most part at least). There were no logically derived priorities in play. Note that my hotspots thesis is but one way of postulating a priority ranking, and there are a lot of others, despite protests from some quarters that I was seeking a monopoly over conservation options.

Which tropical hotspots are in most urgent need of protection and management?

The hotspots in most urgent need of protection and management are Madagascar, Philippines, Sundaland, the Atlantic coastal forest of Brazil, the Caribbean, Indo-Burma, Western Ghats/Sri Lanka, Eastern Arc, the coastal forests of Tanzania/Kenya and the Mediterranean Basin.

Do you think that the current media focus on climate change is shifting emphasis away from the more immediate, direct threats to biodiversity such as deforestation?

No. The current media focus on climate change should surely be complementary to long-standing and more immediate threats such as tropical deforestation. But note that all major environmental issues of today are intricately interlinked; for instance, deforestation can often increase the warming effect of climate change (bare earth absorbs more heat than thick vegetation).

What are the most urgent research problems now facing tropical conservation biology?

I consider that the urgent research problems facing tropical conservation biology are: (1) What are the socioeconomic and politicocultural factors that serve as root causes of deforestation (e.g. perverse subsidies)? (2) What are some interdependencies at work, e.g. how far does forest conservation and reforestation in temperate and boreal zones merely shift logging pressure onto tropical forests? (3) Which sectors of tropical biotas could serve as evolutionary hotspots, i.e. communities that can foster ‘bounce-back’ processes, notably speciation, when the current biotic crisis has played itself out?

In your opinion, in what condition will tropical ecosystems be at the end of the twenty-first century?

I fear that by the end of the twenty-first century tropical ecosystems will be badly battered, at best, owing to population pressures, socioeconomic forces and political incompetence and/or ignorance and/or corruption. But year 2100 is far too distant – as is 2050 – for one to make any informed or rational prognosis.

imminent – 20% of 1.1 billion people inhabit these areas (Cincotta *et al.* 2000). More worryingly, between 1995 and 2000, the human population expanded by 1.8% annually in these hotspots, which is a much higher rate than the average annual expansion for the whole world of 1.3% (Cincotta *et al.* 2000). This trend suggests that, in these hotspots, human-induced environmental changes are likely to proceed more rapidly than in other parts of the world (Cincotta *et al.* 2000; Shi *et al.* 2005). Conservation intervention is, therefore, absolutely necessary in these areas. Myers *et al.* (2000) calculated that, on average, US$20 million per year is needed to safeguard each hotspot – which amounts to a total of about US$500 million annually – a value many orders of magnitude lower than the US$1.4 trillion that global citizens spend in subsidies to degrade environments and economies alike (Myers 1999).

Conservation International has expanded Myer *et al.*'s (2000) analyses and now identifies 34 biodiversity hotspots (www.biodiversityhotspots.org). These hotspots once encompassed 16% of the earth's land surface, but the collective loss of 86% of vegetation means that their land coverage has now been reduced to 2.3%. Harbouring 50% and 42% of world's vascular plant and vertebrate species, respectively, these hotspots are clearly exceptionally rich in biodiversity. Out of the 34 hotspots (see Figure 1.1), 20 are located within the tropics, and biotas in these hotpots are severely imperilled. Seventy-seven per cent (1367 of 1770), 73% (898 of 1213) and 51% (568 of 1101) threatened amphibian, bird and mammal species are endemic to one or more of these declining hotspots (Figure 1.29).

Care should be taken when delineating biodiversity hotspots, as illustrated by Orme *et al.* (2005) using data collected on breeding birds. They showed that, depending on which of three different aspects of avian diversity was used as a basis of determination (i.e. overall species richness, threatened species richness and endemic species richness), alternative hotspot configurations could be generated that were very different spatially. Only 2.5% of hotspots were common to all three aspects (indices) of avian diversity. Orme *et al.* (2005) postulated that these disparities could have originated from differences in rates of speciation, past extinctions and anthropogenic influences that affect measures of diversity. Their study shows that conservation efforts will be aided if targets for conservation are clearly defined before delineating hotspots. For example, threatened or endemic (or, preferably, both) status should take precedence over other diversity indices if species conservation is the goal. This also is the most logical method because of the urgent need to stem the global biodiversity crisis (see Chapter 9).

With similar goals to Myers *et al.* (2000) and Conservation International, BirdLife International has identified 218 Endemic Bird Areas (EBAs) worldwide (Stattersfield *et al.* 1998). Out of 10 000 bird species, 2500 have restricted ranges ($< 50\,000\,km^2$). In addition to being endemic to an EBA, half of all range-restricted

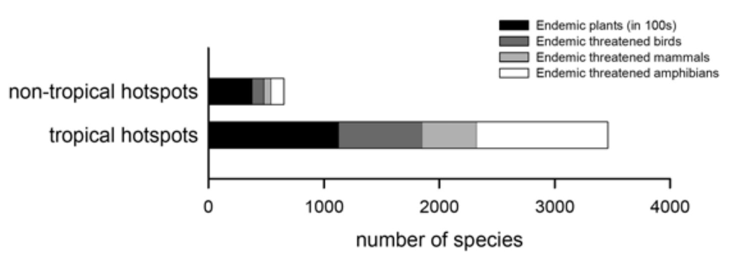


Figure 1.29 The total number of endemic plants and threatened endemic animals between tropical and non-tropical biodiversity hotspots. (Data derived from Orme *et al.* 2005.)

bird species are threatened, making them a high priority for conservation. The EBAs identified have distributions of two or more range-restricted species that overlap, making them richer in endemic bird species by comparison with the rest of the planet. Collectively, these EBAs occupy 4.3% of the earth's land surface, with 77% of them located in the tropics, affirming the paramount conservation value of this region. Indeed, the countries with the highest number of EBAs are all tropical: Indonesia (24), Mexico (18), Peru (16), Brazil (15) and Colombia (14). Eighty-three per cent of EBAs are located in forested areas, particularly tropical forests. BirdLife International considers habitat conservation in EBAs critical for maintaining global avian biodiversity.

Critics claim that instead of allocating conservation priorities based on taxonomic groups conservation should target a range of habitats within terrestrial, freshwater and marine ecosystems on the basis that these protect vital ecological processes (e.g. seed dispersal) and ecosystem services (e.g. carbon sequestration; Olson and Dinerstein 1998). The World Wide Fund for Nature (WWF) has developed an approach known as the Global 200, in which 238 eco-regions are prioritized for conservation because they represent all ecosystems and habitat types present on Earth (Olson and Dinerstein 1998; www.panda.org). An eco-region is defined as a unit of land or water harbouring geographically distinct species assemblages and environmental conditions. Eco-regions are prioritized based on a formulaic combination of indices of relevance to biodiversity conservation: their species richness, endemism, taxonomic uniqueness, unusual ecological or evolutionary phenomena and global rarity. Of these 238 eco-regions, 143 are terrestrial, 53 freshwater and 43 marine. Terrestrial realms dominate the critical eco-regions because they have higher endemism than aquatic realms (Olson and Dinerstein 1998). However, this could also be a reflection of the gaps in information regarding aquatic realms. The aim of this mode of conservation planning is that biomes containing unique ecosystems and species assemblages such as tundra are not ignored in favour of species-rich tropical forests. Similarly, Hoekstra *et al.* (2005) attempted to determine which biomes should be given conservation priority. They found that temperate grasslands and savannas, and 'Mediterranean' forests, woodlands and scrub, are the least protected biomes (< 6% area protected). Tropical broadleaf forests received relatively high protection (16%). Unfortunately, many of the so-called 'protected areas' in the tropics are receiving only 'paper protection' and, in reality, continue to lose area and biodiversity (Curran *et al.* 2004; DeFries *et al.* 2005). Taking a somewhat different tack, Cardillo *et al.* (2006) identified priority conservation areas for mammals based on 'latent' extinction risk – areas that contain diverse mammalian assemblages but are at high risk from future rather than present land use and climate change. Despite their different methods, all of the approaches of strategizing conservation we have described above show a reasonable degree of congruence. For instance, 60% of Global 2000 eco-regions and 78% of EBAs overlap with the biodiversity hotspots (www.biodiversityhotspots.org), and the primary focus for conservation efforts is clearly and consistently identified as the tropical realm.

1.4 Summary

Tropical habitats are disappearing extensively and rapidly.

1. Drivers of this massive ongoing land conversion relate largely to the ever-burgeoning human population and its related activities such as agriculture, urbanization and logging.
2. Weak institutions and rampant corruption thwart efforts to curb tropical habitat loss.
3. Tropical habitats are critical for global biodiversity and should be adequately protected.

1.5 Further reading

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