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Land Transformation and its Consequences

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TRANSFORMATIONS

Global change has many facets; key human interactions with the environment include changes to land-use and land-cover that can alter biochemical cycles and affect the climate system. If the goal of achieving sustainable development in the context of global change does not consider human dimensions, well understood biogeochemical processes will have little practical meaning.

Terrestrial ecosystems are among the most threatened systems since they are more readily accessible and utilized. The recent impressive economic growth in the Southeast Asian region has been based on its natural resources. The consequences are observable in one generation. Land transformation through conversion of natural forests, urbanization and industrialization, and the over-exploitation of coastal zones has had phenomenal impacts on biogeochemical cycles and biodiversity (Sodhi et al. 2004). Tropical rainforests and their globally significant biodiversity are disappearing as land is transformed for other uses. The fate of many species depends upon what happens outside strictly protected areas. Timber concessions represent an opportunity for biodiversity conservation. Exploitation of timber involves some impact on the flora and fauna, but control over operational practices can influence these effects. There have been reviews on what makes, for example, wildlife species in Borneo sensitive to concession practices and on what might be done to improve such practices (see Meijaard et al. 2005).

Remote sensing and Geographic Information System (GIS) techniques have been extensively used to assess Land-Use and Land-Cover Change (LUCC) dynamics at local, regional and even global scales (Lambin 1997). The techniques implemented at high spatial resolution have proven to be useful tools for monitoring vegetation type, density and structure. In addition, a chronological sequence of assessments may be used to evaluate ecosystem degradation and may indicate the status of functional groups and biodiversity.

Most closed forests in Southeast Asia have been converted, degraded or fragmented. The rates of deforestation shown in Table 4.1.1 during two different periods indicate a significant increase compared with South America. In Africa the rate is decreasing. The increased rate would affect biogeochemical cycle and biodiversity. In Sumatra, for example, it is hard to find substantial areas functioning as "corridors". The Bukit Barisan mountain range, which was originally designed to play such a role for several charismatic species like rhinos, orangutan, and Sumatran tigers, is no longer functioning, as it faces consistent and severe fragmentation. Instead, a mosaic of shrubs/thickets, savannah and grassland is commonly observed (Murdiyarso et al. 2002).

Depending on the extent of fragmentation and land-use intensity, the structure of the landscape is transformed towards aggregated land-uses, such as patches of forest mosaic, smallholder landscape (annual and perennial crops), and monoculture plantation (for production of rubber, pulp and paper and

Table 4.1.1 Differences in deforestation rates across regions

Region/Subregion	1990–2000		2000–2005	
	1000 ha	percent	1000 ha	percent
Eastern and Southern Africa	-1 731	-0.71	-1 702	-0.74
Northern Africa	-1 013	-0.72	-982	-0.73
West and Central Africa	- 1 631	-0.56	-1 356	-0.48
Africa	- 4 375	-0.64	-4 040	-0.62
East Asia	1 751	0.81	3 840	1.65
South and Southeast Asia	-2 578	-0.83	-2 581	-0.98
Western and Central Asia	34	0.08	14	0.03
Asia	-792	-0.14	1 003	-0.18
Europe	877	0.09	661	0.07
North and Central America	17	n.s	-101	-0.05
South America	-3 802	-0.44	- 4 251	0.50
World	-8 668	-0.22	-7 317	-0.18

Note: n.s. = not significant.
Source: Table 2.4 in FAO (2005), p. 20.

palm oil) (Tomich et al. 1998). Deforestation, by transforming complex natural ecosystems to more simple structures with specific purposes, also alters the ecosystem services.

CONSEQUENCES ON BIOGEOCHEMICAL CYCLES

Biogeochemical cycles—biological, geological, and chemical processes that move various elements around at plot, landscape, ecosystem, and biome levels—involve all spheres of the earth system. These cycles involve complex processes in the terrestrial, aquatic, oceanic and atmospheric spheres as well as fluxes across these spheres. The cycles may be natural, but in many cases are accelerated by human influences.

Removal of biomass from the terrestrial systems causes not only the release of carbon and other nutrients but also reduces the capacity of the systems to sequester the excessive carbon pool in the atmosphere. Fluvial systems play an important role as conduits for the dissolved elements into the aquatic and oceanic systems of the coastal zones.

LUCC and the global carbon cycle

There is a considerable interest on the role of terrestrial ecosystems in the global carbon cycle. The Intergovernmental Panel on Climate Change (IPCC) in its second assessment report indicated that the global net annual growth of atmospheric carbon in the 1980s was 1.4 giga tons of carbon (Gt C) (IPCC 1995), whereas in the 1990s it had more than doubled, with an annual growth of 2.9 Gt C, as shown in its third assessment report (IPCC 2001).

Land-use change in the tropics has steadily contributed more than 20 percent of the annual increase. Among tropical regions, South and Southeast Asia are the largest contributors from LUCC and deforestation activities (Table 4.1.1). However, tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon (C) pools (e.g. reduced impact logging), expansion of C sinks (e.g. reforestation, agroforestry), and substitution of wood products for fossil fuels (Brown et al. 2000). In tropical Asia, it is estimated that reforestation, agroforestry, regeneration and avoided deforestation activities have respectively the potential to sequester 7.50 Gt C, 2.03 Gt C, 3.8–7.7 Gt C, and 3.3-5.8 Gt C between 1995–2050 (Brown et al. 1993).

Carbon budgets and deforestation

In general, logging leads to a reduction of carbon stocks in the forest as biomass is reduced by the extraction of wood. Carbon is released upon the decomposition

Table 4.1.2 Biomass and carbon density (ton/ha) of tropical forests in Asia

Status	Closed-broadleaf	Closed-conifer [a](ton/ha)	Open forest
Undisturbed-productive	196.3 (98.2)	144.9 (72.5)	79.0 (39.5)
Logged	93.2 (46.6)	112.5 (56.3)	26.32 (13.16)
Percentage decline	53	22	67

Note: [a]in parenthesis.
Source: Brown et al. 1993.

or burning of slash and litter. However, regenerating trees sequester carbon back to biomass over time. In general, the biomass and carbon density of tropical forests in Asia declines by 22 to 67 percent after selective timber extraction (Table 4.1.2).

Detailed studies in Sumatra, Indonesia, indicate that the declining carbon density due to logging may be compensated for by high yielding tree crops. Commercial logging of natural forest areas is followed by plantations of forest trees or perennial crops. This land-use change is expected to reduce carbon stocks. The time-averaged studies that directly measure the change of carbon stocks as a result of this change through time is shown in Table 4.1.3. Averaging the carbon stocks over the lifespan of a system was used to give a simple measure of its role in the global carbon balance, as long as different stages of the system may be expected to occur in roughly proportional areas at any point in time. If we assign a typical "time-averaged carbon stock (Mg/ha)" to each land-use type, we can directly evaluate how "land-use change" will lead to net carbon release or net carbon sequestration, depending on the sign of the difference of "carbon stocks (after)—carbon stocks (before)". This means an evaluation of the carbon stocks of a land-use type depends on the context and the types of comparisons made.

Compared to natural forest, all other land-use types lead to net carbon release to the atmosphere. Compared to continuous annual crops, all other land-uses lead to carbon sequestration. Lowland tropical rainforests have the highest standing biomass and above-ground carbon stocks of any vegetation in the world, and total carbon stocks of rainforests are only equaled by the deepest peat soils. Measurements in Jambi (Murdiyarso et al. 2002) indicate total carbon stock of natural forests on the peneplain can be up to 500 Mg/ha,

Table 4.1.3 Time-averaged carbon stocks in various land-uses following logging of lowland tropical forests in Sumatra, Indonesia

Land-use type ($Mg\ ha^{-1}$)	Age (yr)	Carbon density	Remarks
Forests	40– >100	150–254	Ranging from undisturbed lowland forests to community-based timber producing forests, and large scale logged-over forests
Tree crops	10–40	60–116	Mainly rubber agroforests and plantation with growing area of productive oil-palm and small percentage of fast-growing tree species
Annual crops	3–7	39–74	Upland rice with short (3–5 yr) and long (10 yr) fallow rotations. Abandoned lands may be invaded by *Imperata cylindrica* grassland

Source: Murdiyarso et al. 2002.

with roughly 80 percent in live trees, 10 percent in dead wood and 10 percent in the upper 20 cm of soil. In logged forests (about 10 years after the logging event), live tree biomass is substantially reduced, but there is more carbon in dead wood and at least as much in the soil. In cassava fields, total carbon stocks can be reduced to about 10 percent of those in the forest, but soil stocks are still at least half of those in the forest. Moreover, there appear to be few significant differences among forest extraction systems and some tree-based systems regarding carbon stocks and greenhouse gases. The land-use decision, however, depends on the perspectives of interest groups regarding their profitability, sustainability, and global and local environmental benefits (Murdiyarso et al. 2002).

CONSEQUENCES FOR BIODIVERSITY

Much discussion of biodiversity conservation focuses on existence values i.e. preventing species extinction. From a global perspective, the potential contribution of any area to the global goal depends on the "uniqueness" of its flora, fauna, gene pools or ecosystems, not on its local diversity per se. Much less attention has been given to the local functional values of biodiversity in the landscape. These values range from the tangible (but not yet well quantified) roles of biodiversity in supporting sustainability and resilience of production systems, to less tangible aesthetic and spiritual roles of biodiversity for local people (van Noordwijk and Swift 1999).

Timber extraction and forest fragmentation affect species in different ways. Timber extraction modifies the physical environment, such as nest sites, cover, home range needs, or a moist leaf litter and understorey (Meijaard et al. 2005; Meijaard et al. 2007a), and thereby affects species that depend on these features. Larger-scale fragmentation, on the other hand, is more likely to influence population characteristics such as demography and dispersal processes because it reduces effective population sizes. Fragmentation also affects species at individual and autoecological levels, including survival rates in smaller patches (Laurance 2001; Swihart et al. 2003). This in turn influences reproductive rates, recruitment and demographic ratios. Edge effects and the ability of different species to move through matrix or degraded forest habitats are poorly known in Southeast Asia. Such information is, however, vital to understanding persistence in highly fragmented landscapes.

Nonetheless, various studies suggest that in many circumstances hunting is the primary threat to wildlife (Bennett and Robinson 2000). Forest habitat modification, fragmentation of cover and hunting, acting individually or in concert, can each pose a serious threat to wildlife. However, steps can be taken to address these threats.

Sensitive species

Meijaard et al. (2005) compiled information from a range of sources, including 280 publications and reports (153 in peer-reviewed journals) specifically addressing wildlife in Borneo, consulted various local and international experts, and examined various unpublished data sets. From these the authors sought to characterize species by a number of factors.

Using multivariate meta-analyses, they identified factors associated with vulnerable vertebrate species of the dryland dipterocarp forest. These were dietary specialization, restricted feeding strata, endemicity, apparent evolutionary age (those that evolved during the Miocene or Early Pliocene) and absence from small islands (though some widespread species, such as mouse-deer *Tragulus* spp., are sensitive). Terrestrial insectivores and frugivores appear particularly sensitive, whereas herbivores and omnivores are more tolerant or even benefit from logging. Typically the wider the ecological niche of a species, the more tolerant it is to change. Such findings are useful for developing hypotheses regarding inadequately researched species such as the endangered *Catopuma badia,* the Bornean Bay Cat and *Pardofelis marmorata,* the Marbled Cat, which appear likely to be sensitive (Meijaard et al. 2005; Meijaard et al. in press).

Associated threats

Opening concessions in primary forest brings threats beyond timber extraction (Meijaard et al. 2005). Problems are caused by increased flammability, invasion by weeds and exotic species, and substantial sediment loads in rivers. Increased accessibility and the provisioning needs of logging camps can escalate hunting. Camp staff themselves often set traps, trade in rare birds, and fish using harmful techniques. Roads, skid trails and degraded areas lead to fragmented cover. Divided populations, such as those created by fragmented or heavily harvested landscapes, are at much greater risk of various deleterious effects that can ultimately lead to local extinction. The effects of fragmentation are worst in forests with excessive road density, wide clearings, and many large deforested openings. Forest edges can generate deleterious effects, which may extend considerable distances into undisturbed forests (Gascon et al. 2000; Laurance 2000).

Island populations

Studies suggest that fragmentation affects a broader range of bird species—omnivores, insectivores, frugivores and nectarivores—than does selective logging, though various generalists and non-forest species increase in density (Lambert and Collar 2002). No detailed studies have been conducted on fragmentation's effects on Sundaic mammals. Observations of island populations (within the Sundaic region) suggest that forest areas smaller than ca. 5,000 km^2 are unable to sustain viable populations of large carnivores, unless regular immigration opportunities are provided and hunting is curtailed (Meijaard et al. 2005). Surprisingly, smaller carnivores and insectivores (Herpestidae, Soricidae, Tarsiidae and Mustelidae) also appear restricted to larger islands implying that they too need large forest areas. Such vulnerability appears to relate to the trophic level. At the other end of the spectrum, the ungulates (pigs, deer and mouse-deer) occur on many islands, including small ones. The herbivorous Flying Lemur (*Cynocephalus variegatus*) also survives in many small areas, including Perhentian Island with a land area of only 2 km^2. Conclusions remain tentative, but simple relationships between body size and extinction risk in habitat fragments seem inadequate to explain the observed patterns. Though island faunas differ from those in mainland forests in various respects, these island data are suggestive (Willis et al. 2005).

Rubber agroforests

It was reported that agroforests allow a substantial part of the local flora and fauna to survive within the context of an extensively managed land-use type (Thiollay 1995; Salafsky 1993). However, conversion of natural forests to agroforests usually involves a significant reduction in overall species richness. From a 100 m transect line in Sumatra, Michon and de Foresta (1995) found over 350 species in primary forests while the number dropped to ca. 250 species in rubber agroforests.

MAKING LAND TRANSFORMATION MORE SUSTAINABLE

The removal of forests by clear felling or slash-and-burn practices causes a decrease of carbon stocks by as much as three orders of magnitude (Brown et al. 1993; Lasco 2002). Land-use and land management are a major focus for sustainable development in many developing countries. In reality several options between maintaining forests (carbon) and developing land can meet sustainable development objectives. Land-use decisions following the complete and incomplete removal of forests may now be made on a sound scientific basis as far as sustainable development objectives are concerned. Deforestation is not a binary choice between forest and non-forest. The development of timber and oil palm plantations, practicing simple or complex agroforestry, is among the options that can be considered where trade-offs and complementarity can be demonstrated.

Forest management improvements should address two primary goals:

- to maintain large well-connected forest landscapes (including unlogged areas) containing as complete as possible a range of local forest types, and maintaining the key landscape elements and wildlife resources within these forest landscapes; and
- to identify the major threats to forest wildlife in these landscapes and take steps to address them.

Concessions can be improved to benefit wildlife by good conservation planning, good road building, reduced-impact logging and control over hunting (Meijaard and Sheil 2007a). Specific recommendations include the retention of ecologically important habitat structures (large trees, hollow trees, fruiting species) and locations (salt licks, watercourses). It is recommended that understorey slashing (currently a legal requirement) be discontinued (Sheil et al. 2006). It is important to retain a contiguous forest to maintain various wide-ranging and low-density species (Meijaard and Sheil 2007b). At the concession level, retaining linear forest elements (e.g. riverine forests) as corridors between forest blocks can increase faunal dispersal and thus the chances of species survival in forest patches. Reducing the width of roads and tracks and limiting felling-gap sizes should also reduce the effects of fragmentation on arboreal species (Meijaard et al. 2005).

Many specific actions may help the conservation of specific species (see Meijaard et al. 2006). Examples include large areas for large carnivores (Malayan Sun Bear, Clouded Leopard) and the retention of large stems for Helmeted Hornbill nesting. Pools, wallows and riverside habitats offering nesting opportunities for reptiles and amphibians also warrant protection. There are many areas where effective biodiversity-friendly forestry management is limited by our lack of knowledge. Nonetheless, substantial improvements of current practices are attainable. Not everything can be prescribed by rules and regulations: ideally well-trained and committed managers are needed in the field.

The results of the changed activities will significantly contribute to the understanding of the interactions between humans and their biophysical environment. Changes in land-use and land-cover, which were quantified in terms of C-stocks and biogeochemical cycles, give the necessary insights for the policy community and the resource managers to make decisions that address the concerns of stakeholders.

The activities are highly relevant to public policy-making. Current understanding on the dynamics of LULC should be brought into public policy for three reasons: first, to increase the awareness of the policy community on the importance of terrestrial ecosystems for biodiversity and of associated carbon stocks in a global carbon budget; second, to strengthen their capacity in public policies that address the concerns of local communities and national interests; and third, to improve their confidence in the negotiation processes related to climate change and the roles of terrestrial ecosystems, particularly forests, as sources and sinks of carbon and habitats of endemic species.

References

Bennett, E. L., and J. G. Robinson. 2000. *Hunting of wildlife in tropical forests: Implications for biodiversity and forest peoples.* Washington, D. C.: World Bank.

Brown, S., Iverson, L. R., Prasad, A. and Dawning, L. 1993. "Geographical distribution of carbon in biomass and soils of tropical asian forests". *Geocarto International* 4: 45–59.

Brown, S., Burnham, M., Delaney, M., Powell, M., Vaca, R., and Moreno, A. 2000. "Issues and challenges for forest-based carbon-offset projects: A case study of the Noel Kempff climate action project in Bolivia". *Mitigation and Adaptation Strategies for Global Change* 5 (1): 99–121.

Food and Agriculture Organisation of the United Nations (FAO). 2005. "Global Forest Resource Assessment 2005: Progress toward sustainable forest management". FAO Forestry Paper 147. Rome: FAO.

Intergovernmental Panel on Climate Change (IPCC). 1995. *Climate Change 1995: The Science of Climate Change*. Global Change, 5(1): 99–121. Cambridge: Cambridge University Press.

______. 2001. *Climate Change 1995: The Scientific Basis*. Cambridge: Cambridge University Press.

Gascon, C., G. B. Williamson, and G. A. B. da Fonseca. 2000. "Receding forest edges and vanishing reserves". *Science* 288: 1356–1358.

Lambert, F. R., and N. J. Collar. 2002. "The future for Sundaic lowland forest birds: Long-term effects of commercial logging and fragmentation". *Forktail* 18: 127–146.

Lambin, E. F.. 1997. "Modelling and monitoring land-cover change process in tropical regions". *Progress in Physical Geography* 21: 375–393.

Lasco, R. D. 2002. "Forest carbon budgets in Southeast Asia following harvesting and land cover change". *Science in China* (Series C) 45: 55–64.

Laurance, W. F. 2000. "Do edge effects occur over large spatial scales?". *Trends in Ecology and Evolution* 15: 134–135.

______. 2001. "Fragmentation and plant communities: Synthesis and implications for landscape management". In *Lessons from Amazonia: The ecology and conservation of a fragmented forest*, edited by R. O. Bierregaard, C. Gascon, T. E. Lovejoy, and R. Mesquita, pp. 158–168. New Haven: Yale University Press.

Meijaard, E., D. Sheil, R. Nasi, D. Augeri, B. Rosenbaum, D. Iskandar, T. Setyawati, M. J. Lammertink, I. Rachmatika, A. Wong, T. Soehartono, S. Stanley, and T. O'Brien, 2005. *Life after logging: Reconciling wildlife conservation and production forestry in Indonesian Borneo*. Bogor: CIFOR, ITTO and UNESCO.

Meijaard, E., and D. Sheil. 2007a. "The persistence and conservation of Borneo's mammals in lowland rain forests managed for timber: observations, overviews and opportunities". *Ecological Research*. DOI 10.1007/s11284-007-0342-7.

______. 2007b. "A logged forest in Borneo is better than none at all". (correspondence) *Nature* 446: 974.

Meijaard, E., D. Sheil, A. J. Marshall, and R. Nasi. (2008). "Phylogenetic age is positively correlated with sensitivity to timber harvest in Bornean mammals". *Biotropica* 40 (1): 76–85.

Meijaard, E., D. Sheil, R. Nasi, S. E. Stanley, 2006. "Wildlife conservation in Bornean timber concessions". *Ecology and Society* 11(1): 47. http://www.ecologyandsociety.org/vol11/iss1/art47/

Michon, G., and H. de Foresta. 1995. "The Indonesian agroforest model: Forest resource management and biodiversity conservation". In *Conserving biodiversity outside protected areas: The role of traditional agro-ecosystems*, edited by P. Halladay and D. A. Gilmour, pp. 90–106. Gland: IUCN.

Murdiyarso, D., M. van Noordwijk, U. R. Wasrin, T. P. Tomich, and A. Gillison, 2002. "Environmental benefits and sustainable land-use in Jambi transect, Sumatra, Indonesia". *Journal of Vegetation Science* 13: 429–438.

Sheil, D., R. Puri, M. Wan, I. Basuki, M. van Heist, N. Liswanti, Rukmiyati, I. Rachmatika, and I. Samsoedin. 2006. "Local people's priorities for biodiversity: Examples from the forests of Indonesian Borneo". *Ambio* 35: 17–24.

Sodhi, N. S., L. P. Koh, B. W. Brook, and P. K. L. Ng, 2004. "Southeast Asian biodiversity: An impending disaster". *Trends in Ecology and Evolution* 19: 654–660.

Swihart, R. K., T. M. Gehring, M. B. Kolozsvary, and T. E. Nupp. 2003. "Responses of 'resistant' vertebrates to habitat loss and fragmentation: The importance of niche breadth and range boundaries". *Diversity and Distributions* 9: 1–18.

Thiollay, J. M. 1995. "The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra". *Conservation Biology* 9: 355–353.

Salafsky, N. 1993. "Mammalian use of a buffer zone agroforestry system bordering Gunung Palung National Park, West Kalimantan, Indonesia". *Conservation Biology* 7: 928–933.

Tomich T. P. , M. van Noordwijk, S. Budidarsono, A. Gillison, T. Kusumanto, D. Murdiyarso, F. Stolle, and A. M. Fagi, 1998. "Alternatives to slash-and-burn in Indonesia": Summary Report and Synthesis Phase II. ASB Indonesia Report no. 8. Bogor: ICRAF.

van Noordwijk, M. and M. J. Swift, 1999. "Belowground biodiversity and sustainability of complex agroecosystems". In *Management of agrobiodiversity in Indonesia for sustainable land use and global environmental benefits*, edited by A. Gafur, F. X. Susilo, M. Utomo, and M. Van Noordwijk, pp. 8–28. ASB Indonesia Report no. 9. Bogor: Agency for Agricultural Research and Development, Ministry of Agriculture and University of Lampung.

Willis, K. J., L. Gillson, T. M. Brncic, and B. L. Figueroa-Rangel. 2005. "Providing baselines for biodiversity measurement". *Trends in Ecology and Evolution* 20: 107–108.