ECOLOGICAL COMPONENTS OF ENDANGERED FORESTS
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ForestEthics, Greenpeace, Natural Resources Defense Council, and Rainforest Action Network

1. BACKGROUND

The concept of Endangered Forests emerged out of concern over the continuing loss of critical forest ecological values, which has resulted from an increasing array and intensity of stressors throughout the world. Endangered Forests are native forests of high ecological value that require protection from intensive industrial use to maintain these values.

Note that the use of the word "endangered" should not be confused with the U.S. Endangered Species Act (ESA), where the term carries a particular connotation. Under the legal definition of the ESA, endangered means that a species is at risk of becoming extinct—or of ceasing to exist altogether. Not all Endangered Forests are necessarily facing imminent extinction; however, due to the threats posed by one or more stressors (climate change, industrial use, urbanization, etc.), they are in danger of loosing their ability to function as complete and intact, natural ecological communities, and thereby to continue supporting numerous species and essential ecological processes. Vulnerable forests of high ecological value that require protection to maintain these values are what characterize Endangered Forests.

2. INTRODUCTION AND RATIONALE

Consumers and corporations that buy and sell forest products have a growing interest in achieving ecologically sustainable consumption and procurement. Ecological sustainability is defined in this document as, "the capacity of ecosystems to maintain their essential processes and functions and to retain their biodiversity without impoverishment."[1] In the face of the many, growing stressors being placed on the world's forests (highlighted later in this document), the likelihood of reaching this fundamentally important goal will require multiple strategies and approaches that will rely on productive interactions among governments, businesses, and consumers.

No single conservation strategy (e.g., creating forest reserves or certified forests) can meet the complex set of challenges facing the world's forests. Some benefits afforded by native forests require protecting large, relatively pristine tracts, with little or no human intervention, whereas others may require well-planned human intervention, such as reinstating natural disturbance regimes or eradicating invasive exotic species. Sustaining ecological functions and values for the worlds Endangered Forests will require multi-scale prescriptions that include additional protection, improved forest management, and restoration.[2]

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[1] Williams, J. 2001. Australia State of the Environment Report 2001 (Theme Report), Department of the Environment and Heritage, Commonwealth of Australia. Available at: www.deh.gov.au/soe/2001/biodiversity/glossary.html (April 2005).
[2] Slosser, N. et al. 2005. The landscape context in forest conservation: integrating protection, restoration, and certification. Ecological Restoration 23(1):15-23.

It is important to emphasize that there remain significant forest areas around the world that require protection from intensive industrial use if they are to maintain their ecological values. These forests are the "Endangered Forests."

Many companies have adopted, or are in the process of adopting, polices promoting preservation or special management of ecologically significant forests, but they need direction from scientists on defensible methods for defining and mapping such forests. The Endangered Forest concept is specifically intended to provide this scientific underpinning with a focus on ecological sustainability.

Ecological sustainability is different from but not incompatible with ***sustainable forest management***, which attempts to simultaneously sustain a full range of economic, societal, and environmental values.[3] Thus, whereas ecological sustainability focuses heavily on sustaining the natural ecological values of forests, sustainable forest management may seek to sustain certain (perhaps lower) levels of ecological values while also managing for economic (e.g., sustained timber production), recreational, or other goals. The concept of sustainable forest management has grown in popularity at the intergovernmental level. For example, the Montréal Process for Criteria and Indicators was created in 1994 with the mission of providing policy makers with information about temperate and boreal forests in support of sustainable forest management. This international effort includes 12 signatory nations that account for 90 percent of the world's temperate and boreal forests in the northern and southern hemispheres and approximately 60 percent of all of the world's forests.[4]

Advocates of the Endangered Forest concept fully recognize the role of these and other sustainable forest management efforts. However, they emphasize sustaining ecological values, which have historically been compromised in favor of economic and social values in forest management decisions.

3. Status and Importance of Forests

Forests cover approximately 3.9 billion hectares or 30 percent of the earth's land surface. This is about half the amount of forested land that was present at the dawn of agriculture roughly 10,000 years ago.[5] Only about a fifth of the world's original forest cover remains in relatively large, undisturbed tracts, with 70 percent of these remaining "intact forests" found in three countries – Russia, Canada, and Brazil.[6] Much of the world's forests are no longer in their original condition, having changed in composition, structure, and function to varying degrees. Fifty-six percent of the world's forests are tropical/subtropical, 44 percent are temperate/boreal, and

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[3] Roundtable on Sustainable Forests. Available at: www.sustainableforests.net/management.php (April 2005).
[4] Montreal Process Working Group. 1998-2005. Available at: www.mpci.org/whatis_e.html (April 2005).
[5] Food and Agriculture Organization of the United Nations (FAO). 2001. State of the World's Forests 2001. Rome, Italy. Available at: http://www.fao.org/forestry/index.jsp (April 2005). AND United Nations Environmental Program's Global Environment Outlook 3 (GEO) 2002, p. 92. Nairobi, Kenya. Available at: http://www.unep.org/GEO/geo3/english/pdfs/chapter2-3_forests.pdf (April 2006).
[6] Bryant, D., et al. 1997. The Last Frontier Forests: Ecosystems and Economies on the Edge. World Resources Institute: Washington, D.C.

approximately 5 percent of the world's forests are currently classified as plantations.[7] In spite of the many changes that have occurred within them, the world's natural forests remain critical to the overall ecological health of our planet; they contain over half of the world's biodiversity, making them the richest of all terrestrial systems.[8]

Forests provide a wide range of socioeconomic and ecological benefits (or ecosystem services). The Millennium Assessment (2005) identified four basic categories of ecosystem services: (1) supporting, (2) provisioning, (3) regulating, and (4) cultural (Figure 1).[9] Supporting services provided by forests such as producing oxygen, rebuilding soils, and cycling nutrients make possible all of the other services.

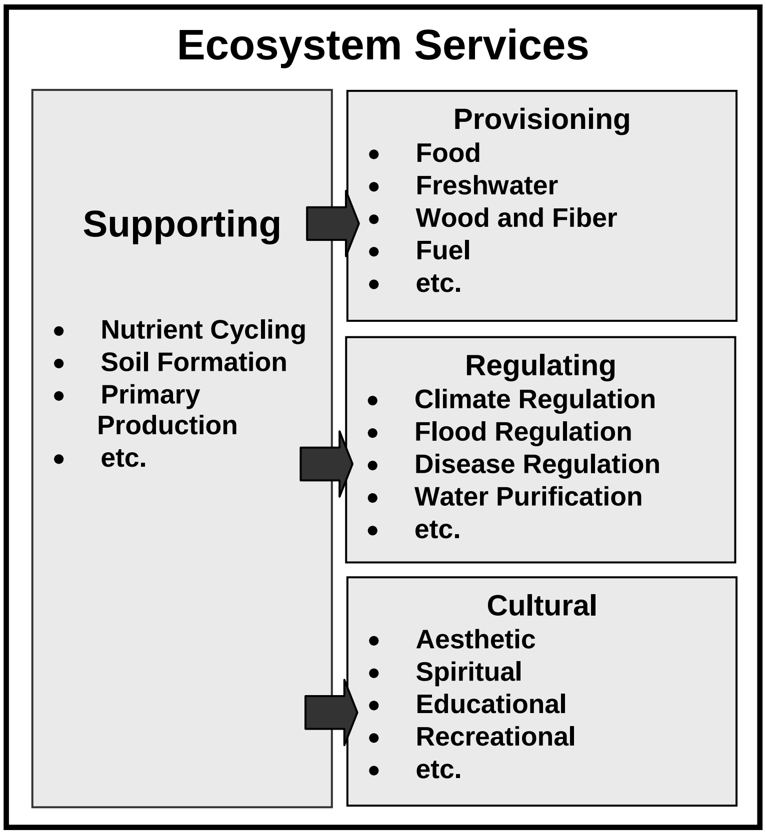

Figure 1. Diagram depicting four classes of ecosystem services as described by The Millennium Assessment (2005).

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[7] Food and Agriculture Organization of the United Nations (FAO). 2001. State of the World's Forests 2001. Rome, Italy. Available at: http://www.fao.org/forestry/index.jsp (April 2005).
[8] UNEP, Convention on Biological Diversity. Forest Biodiversity. Available at: http://www.biodiv.org/programmes/areas/forest/ (April 2004).
[9] The Millennium Assessment. 2005. Millennium Ecosystem Assessment Synthesis Report. Available at: http://www.millenniumassessment.org/en/index.aspx (April 2005).

Under provisioning services, forests provide medicines, food, fuel, and a wide array of wood and other products including building materials and paper products. Because of the direct link to local and global economics, more attention has been paid to this class of service than any other. Human use of forests for obtaining provisions varies markedly among cultures and countries around the world. For example, developed countries produce and consume approximately 70 percent of the world's total value-added wood products (lumber, plywood and veneer, and pulpwood) while developing countries consume roughly 90 percent of the world's fuelwood and charcoal, with the total volume of fuelwood and charcoal slightly exceeding that of industrial roundwood. Global consumption of wood products is approximately 3.3 billion cubic meters per year and rising, and the average consumption rate is 0.55 cubic meters per person per year. Per capita wood use in most developed countries is much higher (e.g., 2.1 cubic meters per person per year in the U.S.).[10] Demand for fuelwood and charcoal is expected to increase at a rate of approximately 1.1 percent per year between 1999 and 2010 while the demand for industrial roundwood is expected to increase at a rate of 1.7 percent per year over this same period.[11] World demand for paper and paperboard is forecast to grow from the current 300 million tons to over 420 million tons by the year 2010 or an average growth rate of 2.8% per year.[12]

Forests also provide many essential regulatory services, which, although less obvious to most citizens, have the greatest overall impact on human well-being[13]. Until recently, these essential services have been largely regarded as "intangible benefits" or "economic externalities"[14] even though their combined value has been estimated to exceed US$4.7 trillion – or about 10 percent of the gross world product.[15] Among their many regulatory services, forests moderate water flow into rivers and streams; prevent erosion; and filter and purify water.[16] They regulate local temperature, moisture, and weather conditions[17] and serve as a major regulator of global climate. Forests remove the primary greenhouse gas (CO_2) from the atmosphere and exude oxygen. In fact, forests systems including soils hold about 62–78 percent of the world's terrestrial biospheric carbon, more than any other ecosystem.[18]

Forests provide numerous cultural values that cannot be quantified but whose impacts are immense. Forests have frequently played a major role in shaping human societies since the

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[10] Howard, J.R. 1999. U.S. timber production, trade, consumption, and price statistics 1965-1997. General Technical Report FPL-GTR-116. USDA Forest Service, Forest Products Laboratory. Madison, WI.

[11] Food and Agriculture Organization of the United Nations (FAO). 1999. State of the World's Forests 1999. Rome, Italy. Available at: http://www.fao.org/forestry/index.jsp (April 2005).

[12] ABARE-Jaakko Pöyry. 1999. Global Outlook for Plantations. ABARE Research Report 99.9, Canberra.

[13] The Millennium Assessment. 2005. Millennium Ecosystem Assessment Synthesis Report. Available at: http://www.millenniumassessment.org/en/index.aspx (April 2005).

[14] Daily, G.C. (editor). 1997. Nature's Services. Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

[15] Larsen, J. 2002. Forest cover shrinking. Earth Policy Institute. Available at: http://www.earth-policy.org/Indicators/indicator4.htm (April 2005)

[16] Maltby, E. 1997. Peatlands: The science case for conservation and sound management. Pages 121-131, in: Parkyn, L., et al. (editors) Conserving Peatlands. Centre for Agriculture and Biosciences (CAB) International, Wallingford, U.K.

[17] Hall, J.P., et al. 1990. A Forestry Canada approach to environmental forestry. The Forestry Chronicle 66 (2): 138-142.

[18] Intergovernmental Panel on Climate Change. 2001. IPCC Special Report on The Regional Impacts of Climate Change An Assessment of Vulnerability. Available at: www.grida.no/climate/ipcc/regional/index.htm (April 2004).

origin of man. Based on existing data, approximately 2/3 of the known ethnolinguistic centers originated in temperate and tropical forest biomes. Many peoples remain strongly linked to the ecosystem services provided by forests, and forests remain firmly integrated into their economies, religions, values, beliefs, and rituals. For many people living in industrialized nations, personal links to forests has been severed to varying degrees, but the almost innate love for forests remains.

4. THREATS TO FORESTS

Threats to native forests are severe and growing. From the onset of the Industrial Revolution, forests have undergone dramatic and widespread changes. Over the past 50 years, humans have changed natural ecosystems (including forests) faster than in any other period in human history.[19] Driving many of these threats is a growing human population, which is currently over 6 billion and doubling every three to four decades. The human population is expected to nearly stabilize at just over 10 billion by 2200.[20] Based on today's consumption rates, demand for wood products alone would increase from 3.3 billion cubic meters per year today to 5.2 million cubic meters per year by 2050.[21] However, this does not take into account the spread of technology and the concomitant increase in resource consumption, which is currently doubling every decade or two. The combined effect of human population growth and increased per-capita resource use amplifies environmental impacts.[22]

Forests must contend with both deterministic (or direct) impacts (e.g., logging, road building, and mining) as well as stochastic ones (e.g., wildfire and disease). Direct impacts are significant and expected to increase over time as the human population grows and demand for forest products swells. Managing and monitoring forests under the best of conditions is becoming increasingly challenging, and made far more difficult by the large levels of illegal logging in some parts of the world. Illegal logging is also an increasing threat to forests worldwide, especially in Indonesia where the government estimates that as much as 90% of the country's timber production is unlawful.[23]

Numerous studies demonstrate synergistic effects from multiple stressors acting concurrently on forests. The combined effects of factors such as logging, fire, insect pests, livestock grazing, and invasive alien species have had profound and often unpredictable negative consequences in many native forests.[24] Furthermore, it may take decades for a species to disappear from a landscape after a point of no return has been surpassed by multiple (sometimes compounding) stresses.

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[19] The Millennium Assessment. 2005. Millennium Ecosystem Assessment Synthesis Report. Available at: www.millenniumassessment.org/en/index.aspx (April 2005). AND Vitousek, P.M., et al. 1997. Human domination of the Earth's ecosystems. Science 277:494-499.

[20] UN, Department of Economic and Social Affairs Population Division. Available at: www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf (April 2005).

[21] Society of American Foresters. 2005. World forestry: A position of the Society of American Foresters. Available at: www.safnet.org/policyandpress/psst/WorldForestry_6302.cfm (April 2005).

[22] Woodwell, G.M. 2001. Forests in a Full World. Yale University Press, New Haven, CT.

[23] Greenpeace. April 2006. Kayu Lapis Indonesia, the Untouchable God of Indonesian ancient forest destruction

[24] Lindenmayer, D. 1995. Disturbance, forest wildlife conservation and a conservative basis for management in the mountain ash forests of Victoria. Forest Ecology and Management 74:223-231.

The leading threats to biodiversity, which E.O. Wilson terms the "mindless horsemen of the environmental apocalypse," are habitat destruction, alien invasive species, overexploitation, and exotic disease.[25] Some would add pollution as a fifth horseman[26], and climate change could soon equal or surpass habitat destruction as the leading cause of species endangerment. The Millennium Assessment created a matrix showing levels of impact from five major drivers of biodiversity decline for three major forest biomes (Table 1).

Table 1. Matrix showing five major drivers of biodiversity decline for the three major forest biomes. Shaded boxes denote impact over the last century (black = very high; medium gray = high; light gray = moderate; white = low) and the arrows indicate current trends (arrow straight up = very rapid increase of impact; arrow angled up = increasing impact; horizontal arrow = continuing impact; and arrow angled down = decreasing impact).[27]

	Habitat Destruction	Climate Change	Alien Invasive Species	Overexploitation	Pollution (e.g., nitrogen)
Boreal Forest	↗	↑	↗	→	↑
Temperate Forest	↘	↑	↑	→	↑
Tropical Forest	↑	↑	↑	↗	↑

Habitat Destruction

The Millennium Assessment reports that habitat destruction remains the leading immediate threat to the world's forest biodiversity, particularly in tropical and boreal forests, which were many of the same regions reported as having high levels of "***frontier forest***s" as reported by Bryant et al. (1997) including the Northern Amazon Basin and Guyana Shield, Canadian and Russian boreal regions, Indonesia, and Central Africa.[28] Further support for this assertion in provided by the most recent global FAO Forest Assessment that reports global forest cover was reduced by 2.2 percent between 1990 and 2000, with the most significant changes occurring in Africa (-7.8%), South America (-4.1%), and Oceania (-1.8%). Europe was the only region in the world that posted forest area gains (+0.8%) during this time period.[29] However, it is important to

[25] Wilson, E.O. 1992. The Diversity of Life. Cambridge: Belknap Press of Harvard University Press.
[26] Wilcove, D., et al. 2000. Leading threats to biodiversity. in, Precious Heritage: The Status of Biodiversity in the United States. Oxford University Press, New York, NY.
[27] The Millennium Assessment. 2005. Millennium Ecosystem Assessment Synthesis Report. Available at: www.millenniumassessment.org/en/index.aspx (April 2005).
[28] Bryant, D., et al. 1997. The Last Frontier Forests: Ecosystems and Economies on the Edge. World Resources Institute: Washington, D.C.
[29] Food and Agriculture Organization of the United Nations (FAO). 2001. State of the World's Forests 2001. Rome, Italy. Available at: www.fao.org/forestry/index.jsp (April 2005).

point out that measuring changes in forest cover is difficult due to the lack of direct measurement and complexity of using remote sensing in global monitoring. In fact, independent studies in Indonesia and Brazil suggest that FAO results tend to underestimate actual forest loss.[30]

Deforestation is expected to continue in many of the same regions that posted losses over the last decade. However, there is more to habitat destruction than conversion, and much more forested land is impacted each year than can be effectively monitored by global or national assessments. Even in regions where total forest area is increasing or stable, forest health is being degraded by various impacts that operate at regional and local scales, such as (1) reduction or elimination of old growth seral stages; (2) changes in natural forest composition; (3) conversion of native forest to plantation forests; (4) livestock grazing; (5) damage to soil fertility; (6) road building; (7) forest fragmentation; and (8) alteration of ***natural disturbance regimes***.

Plantation forestry is a particularly challenging topic, for it can be both a threat and a partial solution to the forest biodiversity crisis. If applied carefully, plantations can help alleviate pressures on the remaining native forests, because they can produce more wood faster and on less land. In 2000, five percent of the world's forests were classified as plantations, but they produced 35 percent of the roundwood volume; and this proportion is expected to increase to 44 percent by 2020.[31] However, many of the best locations for plantations also contain many native forest biodiversity values. Where native forests are replaced by plantation forests (especially ones planted with exotic trees), native biodiversity can be severely compromised or lost altogether.[32]

Plantation forestry has a long history in Europe, from where it has spread to other regions with increasing demand for wood. In the southeastern U.S., plantation acreage grew from one percent of timbered area in 1952 to 48 percent in 1999[33]; and plantations have expanded rapidly throughout portions of Chile.[34] An increase in plantation forestry is expected to continue particularly in locations where yields can be kept high and production costs low.[35]

Alien Species Invasion

Invasion by alien species is second only to habitat destruction in detrimental effects on biodiversity.[36] Alien invasions tend to be surreptitious, mildly to extremely disruptive to native species and ecosystem processes, and occasionally are ecologically transforming.[37] Sometimes

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[30] UNDP, UNEP, World Bank, and World Resource Institute. 2000. World Resources 2000-2002: People and ecosystems: The fraying web of life.
[31] Food and Agriculture Organization of the United Nations (FAO). 2001. State of the World's Forests 2001. Rome, Italy. Available at: www.fao.org/forestry/index.jsp (April 2005).
[32] Hunter, M.L. 1999. Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press. New York NY.
[33] USDA Forest Service. 2002. Southern Forest Resource Assessment. D. N. Wear and J.G. Greis (editors). Technical Report GTR SRS-53, US Forest Service Southeast Region.
[34] Neira E., et al. 2002. Chile's Frontier Forests: Conserving a Global Treasure. A Global Forest Watch Report. World Resources Institute and US Forest Service.
[35] The Millennium Assessment. 2005. Millennium Ecosystem Assessment Synthesis Report. Available at: www.millenniumassessment.org/en/index.aspx (April 2005).
[36] Wilson, E.O. 1992. The Diversity of Life. W.W. Norton and Company, New York, NY.
[37] Vitousek, P.M., et al. 1997. Introduced species: a significant component of human-caused global change. New

the introduction of alien species are introduced intentionally (for example, exotic tree plantations or introduced game animals), but more frequently alien species are introduced by accident. The risk of introducing alien invasive species has grown recent response to market globalization and increased international trade.

Alien tree diseases and pests have been particularly disruptive, causing widespread damage to regional forest industries and ecological integrity. For example, the American chestnut once accounted for a quarter of the standing timber in eastern North America, and it became the most popular commercial species in the region by the mid-1880s. Ecologically, the American chestnut was a dominant component of the eastern deciduous forest ecosystem upon which many other species depended. In 1904, the New York Zoological Park imported Asian chestnut in the hope of crossbreeding American and Asian forms to produce a tree that provided high-quality timber and large nuts. Unfortunately, the Asian chestnut specimens contained fungus blight to which the American form had no resistance. Within 50 years, the American chestnut was effectively eliminated from eastern North America.[38]

Stressors of forested ecosystems often operate in powerful synergistic ways, reducing our ability to predict the types and magnitude of changes that may occur. For example, habitat disturbance makes forests more susceptible to alien invasions[39], and invading species in turn can alter ***natural disturbance regimes***, thus increasing alien invasion rates even more in a positive feedback loop.[40] These kinds of interactions can lead to substantial ecological changes with fundamental shifts in ecological processes and losses to native species.[41]

Climate Change

Of all the identified drivers of forest biodiversity loss, climate change has the potential to become the leading agent in the coming decades, although its effects remain difficult to predict. Since 1900, the burning of fossil fuels has contributed the most to atmospheric green house gases, although clearing and burning of tropical forests accounts for between 20-25% of anthropogenic greenhouse gases released each year.[42] Forests act in concert with climate – influencing it while at the same time being impacted by it. Prior to 1900, deforestation was the dominant source of increased atmospheric CO_2 (the dominant greenhouse gas). Since then, the burning of fossil fuels has contributed most to greenhouse gases, although harvesting of forests still accounts for 25 percent of released atmospheric CO_2 each year.[43] When large areas are left undisturbed and forest growth exceeds harvest, forests can reduce CO_2 levels in the atmosphere and therefore are important tools for slowing global climate change. Unfortunately, the capacity

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Zealand Journal of Ecology 21:1-16. AND Parker, I.M., et al. 1999. Impact: toward a framework for understanding the ecological effects of invaders. Biological Invasions 1:3-19.

[38] Van Driesche, J. and R. Van Driesche. 2000. Nature Out of Place. Island Press, Washington, D.C.

[39] Orians, G.H. 1986. Site characteristics favoring invasions. Pp. 133-148 In: H.A. Mooney and J.A. Drake (editors), Ecology of Biological Invasions of North America and Hawaii. Springer-Verlag, New York, NY.

[40] Mack, M.C. and C.M. D'Antonio. 1998. Impacts of biological invasions on disturbance regimes. TREE 13:195-198.

[41] Vitousek, P.M. 1986. Pp. 163-178 In: H.A. Mooney and J.A. Drake (editors), Ecology of Biological Invasions of North America and Hawaii. Springer-Verlag, New York, NY.

[42] Moutinho, P. and S. Schwartzman. 2005. Tropical Deforestation and Climate Change. Amazon Institute of Environmental Research.

[43] Metafore. Available at: www.certifiedwood.org (April 2005).

of the world's forests to maintain native composition, structure, and function (including their capacity to sequester carbon) is being increasingly compromised by the multitude of stressors they face.

Predictions concerning the types and severity of changes expected in forest ecosystem composition, structure, and function vary by forest biome and regional history.[44] Most of the world's forests are expected to experience some level of disturbance due to the changing climate, posing a serious threat to global forest biodiversity[45], forest-based economies, and ecosystem services. A growing body of scientific literature indicates that climate changes is already affecting forests by shifting species ranges, fostering pests and pathogens, altering fire disturbance regimes, changing migration patterns, and causing species extinctions. Northern latitude and mountain forest systems are showing the greatest changes. For example, in the Canadian boreal, increased fire frequency and intensity has been reported[46] while climate change is being postulated as the primary cause of some amphibian extinctions in tropical cloud forests.[47]

Recent research also demonstrates a time lag between increasing greenhouse gas concentrations and measurable climate change and associated impacts. This means that even if greenhouse gas concentrations are stabilized, global warming will continue into the future, with even greater changes in the future than those we have already observed.[48] This argues for a rapid and significant response to reducing greenhouse gasses – and forest conservation plays a role in this response.

It is important to evaluate cumulative effects of all stressors acting together in Endangered Forests. This will help in prioritizing which forest areas require the most immediate mapping and protection. Understanding cumulative and synergistic threats is also essential to designing management prescriptions to counter adverse effects.

5. ECOLOGICAL COMPONENTS OF ENDANGERED FORESTS

Ecological components used to define Endangered Forests were derived from key ecological components identified by science-based reserve-design efforts,[49] and are based on an evolving discussion among environmentalists, corporations, and scientists.[50] The components include:

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[44] Watson, R.T., et al. 1997. IPCC Special Report on the Regional Impacts of Climate Change: An Assessment of Vulnerability. Intergovernmental Panel on Climate Change. Available at: www.grida.no/climate/ipcc/regional/198.htm (April 2004).
[45] Food and Agriculture Organization of the United Nations (FAO). 2001. State of the World's Forests 2001. Rome, Italy. Available at: www.fao.org/forestry/index.jsp (April 2005).
[46] Gillett, N.P., et al. 2004. Detecting the effect of climate change on Canadian forest fires. Geophysical Research Letters 31 (18): L18211.
[47] Pounds, A., et al. 1999. Biological response to climate change on a tropical mountain. Nature 398:611-615.
[48] Meehl, G.A., et al. 2005. How much more global warming and sea level rise? Science 307(18):1769-1772.
[49] For example, see World Wildlife Fund's ecoregional assessments, the Forest Stewardship Council's High Conservation Value Forest categories, Conservation International's Biodiversity Hotspots, and World Resources Institute Last Frontier Forests. ALSO SEE: Myers, N., et al. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858. AND Groves, C.R., et al. 2002. Planning for biodiversity conservation: Putting conservation science into practice. BioScience *52*:499-512. AND Wade, T.G., et al. 2003. Distribution and causes of global forest fragmentation. Conservation Ecology 7(2): 7. Available at: www.consecol.org/vol7/iss2/art7

Landscape Integrity Components

1) Intact forest landscapes

Geographically isolated forests

2) Remnant forests and restoration cores, including:

3) Landscape connectivity

Biodiversity Components

4) Rare forest types (composition and structure)

5) Forests of high species richness (alpha and beta diversity)

6) Forests containing high concentrations of rare and endangered species

7) Forests of high endemism

8) Core habitat for focal species (aquatic and terrestrial)

9) Forests exhibiting rare ecological and evolutionary phenomena

<u>Landscape Integrity Components</u>

1) Intact forest landscapes

There is no place on Earth not affected by modern humans[51], but some regions have been more directly and severely impacted than others. We know that natural forest landscapes lose components and functionality as human uses expand and continue over time. Some ecosystem changes can be quite gradual (e.g., loss of interior forest habitat over time) while others are punctuated (e.g., loss of a ***keystone species***). Intactness is not a binary (yes/no) quality, but actually one of degree. One can envision a continuum of intactness from a totally pristine environment on one end to a totally developed environment on the other. Quantifiable and replicable indices and scales of measurement are needed to score landscapes on this continuum. Although significant progress is being made,[52] this area of applied research remains quite young. Nevertheless, although ranking forest landscapes by their relative intactness may be imperfect, it need not be arbitrary. And despite imperfect knowledge, rating forest intactness remains a conservation imperative.

An ***intact forest landscape*** does not necessarily consist of old trees and may not even be entirely forested. Simply stated, ***intact forest landscape***s are contiguous mosaics of natural habitat types (forest and non-forest alike) in forest-dominated ***ecoregions*** that have either never been subjected to industrial human activities or have sufficiently recovered from such activities in the past to the point where the composition, structure, and function of the forest landscape are

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(April 2004).

[50] Sometimes called the "Wye Group" after an early meeting at Wye River, Maryland, the organizations supporting this description of endangered forest values have been working together and with other environmentalists, scientists, and interested corporations to develop Endangered Forests Values.

[51] Vitousek, P.V., et al. 1997. Human alteration of the global nitrogen cycle: sources and consequences. Ecological Applications 7 (3):737-750.

[52] Anderson, J. E. 1991. A conceptual framework for evaluating and quantifying naturalness. Conservation Biology 5 (3):347-352 AND Angermeier, P.L. 2000. The natural imperative for biological conservation. Conservation Biology 14 (2):373-381.

relatively complete. In some localities (e.g., portions of Canada, Russia, Amazonia, Central Africa, Indonesia, and the U.S.), these are the remaining ***frontier forest***s as defined and mapped at a very coarse level by Bryant et al. in 1997 (Appendix B, MAP 1).[53] In other localities, these are forest landscapes that have recovered from previous human disturbance to the point where they possess many if not most of their original forest characteristics (e.g., portions of the eastern U.S. and Canada, eastern Europe, and portions of Asia). It is important to note that these forests are not static. On the contrary, an ecosystem with a high level of intactness is one that is able to maintain its biodiversity and ecosystem functionality over time – not in any fixed, quantitative sense, but rather as a dynamic property.[54]

To a large extent, many of the compositional (e.g., types of species present) and structural (e.g., size of trees and complexity of forest canopy) components of forest landscapes are size-independent. However, ***home range*** needs for some animal species – forests are more than a collection of trees – and many ecological processes (e.g., natural regeneration, natural disturbance, nutrient cycling, predator-prey interactions, and migration and dispersal) require considerable areal extents to operate within their natural range of variability. Therefore, the definition of intact forests landscapes requires a reference to some minimum size. But how large do forest landscapes have to be to be considered intact?

Ecologically, there are two main determinants to help answer this question – (1) ***natural disturbance regimes*** and (2) area requirements for large ***home range*** species. Operationally, the interaction of these two criteria should dictate any minimum size threshold. Unfortunately from a mapping standpoint, both are difficult to rely on for determining <u>absolute</u> size thresholds and both criteria vary greatly from forest type to forest type. The best we can do with available data is to establish threshold estimates based on our current knowledge of these two important ecologically-based considerations for the various forest systems being mapped.

<u>Natural disturbance regimes</u>

If we consider the first criterion – ***natural disturbance regimes*** – we can illustrate how different forest systems require different areal extents in order to accommodate the dominant natural disturbance agent(s) for that forest type. The objective is <u>not</u> to determine the minimum size a single forest landscape must be to accommodate every conceivable natural disturbance event; rather, it is to establish a size threshold for mapping purposes that reasonably reflects the scale of the dominant disturbance agent. For example, fire is the primary natural disturbance agent in boreal forest systems that can impact very large areas. Based on the available data on fires for boreal Alaska and Canada over the last decade, the minimum dynamic area using one proposed technique would be approximately 30,000 ha. [55] However, under extreme weather conditions, fires in the boreal can cover 100,000 - 200,000 ha, and occasionally over 1 million ha, in a single event. How an area naturally recovers after fire depends upon the survival of individual trees

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[53] Bryant, D., et al. 1997. The Last Frontier Forests: Ecosystems and Economies on the Edge. World Resources Institute: Washington, D.C.

[54] O'Neill, R.V., et al. 1986. A hierarchical concept of ecosystems. Princeton University Press, Princeton, N.J. AND Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monographs 62:447-502.

[55] Shugart, H.H. and D.C. West. 1981. Long term dynamics of forest ecosystems. American Scientist 69:647-652.

and small patches (sometimes referred to as legacies),[56] and on the recolonization of species and individuals destroyed by the fire from adjacent undisturbed sites. The area necessary to ensure survival or recolonization of disturbed sites has been termed ***minimum dynamic area***.[57]

The ***minimum dynamic area*** for many boreal forests is obviously quite large, which in part is what led Global Forest Watch to choose 50,000 ha as the minimum size threshold for intactness in boreal forests, which allowed for the consistent mapping of intact forest landscapes for the entire boreal zone (Appendix B, MAP 2).[58]

Catastrophic windthrow (large scale wind damage), especially in wind prone aspects, is a major disturbance agent in coastal temperate rainforests such as in Southeast Alaska and coastal British Columbia, where a single event can impact hundreds of hectares.[59] A reasonable minimum size threshold for these systems might be 5,000 ha, which is the threshold Global Forest Watch has used in Chile, Alaska, and draft maps of intact forests in British Columbia (which were created using satellite images and ancillary data).

In many deciduous forests around the world, phase gap dynamics (the loss of individual trees or small clusters of trees from wind or ice) is the most important ***natural disturbance regime***; phase gap dynamics impact approximately one percent of the forest canopy per year in deciduous forests in the United States.[60] Based on phase gap dynamics, a reasonable minimum size threshold for these systems might be 500 ha.

Home range

The second forest intactness threshold consideration is the area required to maintain viable populations of large ***home range*** forest species. As with natural disturbances, the objective is not to determine the size a single forest landscape has to be to maintain an entire viable population of a given species in this case, but rather to determine a meaningful forest landscape size that provides functional habitat blocks for the particular species being evaluated. In some instances, these areal estimates will fall below the areal estimates for natural disturbance. In other cases, the minimum size of intact forest landscapes will need to be adapted to account for this additional information. For example, a reasonable minimum size threshold for some eastern deciduous forest types is 500 ha. However, if one considers the area requirements for the forest

[56] Perry, D.A. 1994. Forest Ecosystems. John Hopkins University Press, Baltimore.
[57] Pickett, S.T.A. and J.N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biological Conservation 13:27-37.
[58] Yaroshenko, et al. 2001. Last Intact Forest Landscapes of Northern European Russia. Global Forest Watch. Available at: www.globalforestwatch.org/english/russia/maps.htm (12/08/03); Aksenov, D.E., et al. 2002. Atlas of Russia's Intact Forest Landscapes. Global Forest Watch. Available at: www.globalforestwatch.org/english/russia/maps.htm (12/08/03) AND Lee, P., et al. 2003. Canada's Large Intact Forest Landscapes. Global Forest Watch Canada, Edmonton, Alberta. Available at: www.globalforestwatch.ca (April 2004).
[59] Nowacki, G.J. and M.G. Kramer. 1998. The effects of wind disturbance on temperate rain forest structure and dynamics of Southeast Alaska. PNW-GTR-421. USDA Forest Service. AND Pearson, A.F. 2003. Natural and logging disturbances in the temperate rain forests of the central coast, British Columbia. Vancouver, BC: Coast Information Team.
[60] Runkle, J.R. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology 63: 1533-1546.

species with the largest area needs (e.g., black bear), increasing the size threshold may be warranted. In the case of the black bear, a large territorial mammal that occurs in some eastern North American forests, home ranges differ considerably based on various environmental factors such as food productivity, den site availability, and the abundance of escape habitat. Home range needs for black bears range from 1,000 - 5,000 ha for females with young and from 4,500 - 40,000 ha for males who wander more regularly in search for mates.[61] In high productivity and biodiversity-rich areas (i.e., some parts of the southeastern US), forest intactness thresholds should be increased from 500 ha to 1,000 - 2,000 ha.

Geographically isolated forests

Under some circumstances, forest landscapes are naturally isolated and are smaller than the minimum size threshold estimates for mapping intact forest landscapes. These relatively small actual islands or habitat islands should be identified as intact forests if they are undisturbed by industrial activity. In southeast Alaska, for example, there are over 27,000 forested islands smaller than 500 ha most of which have never been impacted by industrial use. Individually they are small, but collectively they cover over 60,000 ha.

In general, intact forest landscapes should be large enough to act as coarse-filter habitat anchors for species that require large ***home ranges*** and should also be large enough to recover from natural disturbance events without losing their ***natural resilience***. In parts of the world where there is not a clear set of size thresholds for the different forest systems, the most pragmatic and useful approach would be to first map the best remaining examples of the <u>relatively large</u> intact forest landscapes for each forest ***ecoregion*** and then to map smaller forest landscape units. This should be done on an ecoregional basis since ecoregions are widely believed to be the most ecologically useful organizing unit for conservation purposes.[62]

Intact forest landscapes form the primary nuclei for maintaining the remaining biodiversity and natural processes in forest landscapes around the world, which in turn, provide extremely important ecosystem services to human societies as outlined earlier in this document. Some of the services operate at global scales (e.g., intact forests are extremely important for regulating global carbon); others operate at regional scales (e.g., intact forests help regulate regional climate); and still others operate at local scales (e.g., intact forests protect local drinking water supplies and stabilize hillsides). Intact areas form one of the most critical components in developing a global framework for ecological sustainability as they form the foundation for regional forest conservation plans. As the world's human population continues to climb along with a simultaneous increase in overall consumption, intact forest landscapes are becoming increasingly rare at the global level.

Examining ecological components at multiple spatial scales is an extremely important aspect of identifying and mapping Endangered Forests. Forest management occurs at the forest management unit level, so there is a natural tendency to consider only a particular forest

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[61] Rudis, V.A. and J.B. Tansey. 1995. Regional assessment of remote forests and black bear habitat from forest resource surveys. Journal of Wildlife Management 59: 170-180.
[62] Olson, D.M., et al. 2001. Terrestrial ecoregions of the world: A new map of life on Earth. Bioscience 51 (11): 933-938.

management unit when addressing Endangered Forests. However, without adequate perspective from global, regional, and subregional spatial scales, it is virtually impossible to evaluate ecological components properly, establish meaningful ecological thresholds, and maintain consistency and replicability. Only by considering multiple spatial scales in relation to the different ecological components can these be achieved (Figure 3). For example, in ecoregions with few remaining intact forest landscapes (e.g., southern boreal ecoregions of Canada), most remaining intact forest landscapes should be identified as Endangered Forests and targeted for strict protection within a regional conservation framework. In ecoregions dominated by intact forest landscapes (e.g., northern boreal ecoregions of Canada), not every intact polygon should be identified as an Endangered Forest based on the criterion of intactness alone. By working through the other ecological components reviewed in this document, a subset would be identified based on their collective value. Under these circumstances, the ***precautionary principle*** would be followed until the remaining values were adequately evaluated. At the conclusion of the assessment, some of the intact forest landscapes would be open for some industrial use provided that the maintenance of ecological integrity remains an overriding guiding principle and that compliance to this end is supported by ongoing monitoring results.

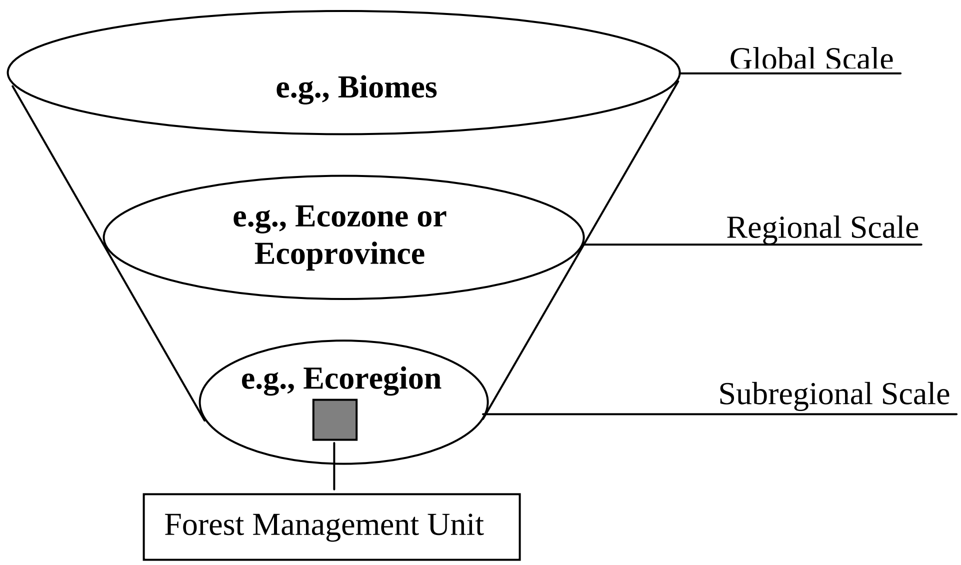

Figure 3. Diagram depicting multiscale assessment units desired for identifying and mapping Endangered Forests.

2) Remnant forests and restoration cores

Remnant forests and restoration cores (or remnant blocks) are the remaining forest landscapes that are globally, ecoregionally, or locally rare as a result of historic and current human activities. It is important to evaluate these remaining forest landscape blocks in all ecoregions, but it is particularly important in those ecoregions that are the most heavily altered by industrial human activities. In some regions of the world, these are the only remaining patches of forest upon which to build a regional forest conservation strategy. Some remnant forests are comprised primarily of native species (relatively intact but small in area), in which case they may be highly prized for protection. More often, these forest landscapes have experienced some losses to their overall natural quality and will require some restoration activities to improve their biological value to the region.

At the global level, heavily altered and degraded regions include: Atlantic Forests of South America, Southeastern Mixed and Coniferous Forests of the U.S., Redwood Forests of the U.S., Lowland Tropical Rainforests of Indonesia, and Tropical Dry Forests of Thailand and Costa Rica. Data on remnant blocks in these areas at the regional and local levels is scattered but important to collect. For example, roadless forest blocks have been mapped for some regions in the United States (e.g., National Forests), but much more work is necessary in many parts of the world.

Once identified and mapped on an ecoregion-by-ecoregion basis, potential remnant blocks should be included as another important building block in Endangered Forest mapping efforts. And as with intact forest landscapes, assessing which blocks would be identified as Endangered Forests will require a solid understanding of their collective values as well as their regional context and history. In regions where there are few or even no remaining intact blocks, remnant blocks become more important, but that does not mean that all remnant blocks would automatically be classified as an Endangered Forest. In ecoregions where remnant blocks are rare, it may be that all of them would be identified as Endangered Forests, but in most areas only the remnant blocks that either possessed the highest conservation value or potential for successful restoration would be designated as such.

3) Landscape connectivity

Overall, habitat loss and fragmentation is considered to be the most important factor leading to the loss of native species (especially in forested landscapes), and to be one of the primary causes of the present extinction crisis.[63] Habitat fragmentation is generally defined as the process of subdividing a continuous habitat type into smaller patches, which results in the loss of original habitat, a reduction in patch size, and the increasing isolation of patches.[64] Depending on the severity of the fragmentation process and on the sensitivity of the ecosystems affected, native plants and animals and many natural ecosystem processes (e.g., nutrient cycling, pollination, predator-prey interactions, and ***natural disturbance regimes***) are compromised or fundamentally altered. For many plant and animal species, migration between suitable habitat patches becomes more difficult, leading to smaller population sizes, decreased gene flow, and possible local extinctions.[65]

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[63] Wilcox B.A. and D.D. Murphy. 1985. Conservation strategy: The effects of fragmentation on extinction. American Naturalist 125:879-887.
[64] Andrén H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71(1994):355-366.
[65] Wilcove, D.S. 1987. From fragmentation to extinction. Natural Areas Journal 7:23-29. AND Vermeulen, J.W. 1993. The composition of the carabid fauna on poor sandy road-side verges in relation to comparable open areas. Biodiversity and Conservation 2:331-350.

Declines in forest species as a result of fragmentation have been documented for numerous taxa including neotropical migrant songbirds,[66] small mammals,[67] and invertebrates.[68] Forest fragmentation has also been closely associated with increased susceptibility to exotic invasion.[69]

To counter the negative effects of forest fragmentation, promoting functional connectivity between existing cores of native habitat is fundamentally important. This can be achieved in the form of actual ***landscape linkages*** (narrow bands of native forest habitat between existing protected areas or other core natural habitats) or by planning for an effective level of ***landscape permeability***. Both of these methods should target area- and habitat-sensitive species. Landscape level connectivity is also important for maintaining broader scale ecological processes (e.g., aquatic-terrestrial interaction, natural plant and animal dispersal, predator-prey interactions, and species migration), and to the degree possible, regional planning should strive to identify important locations where these processes can be supported.

Biodiversity Components

Certain forests worldwide are recognized as containing globally, regionally, or locally significant biodiversity values. Biodiversity components that can be mapped include: rare forest types, species rich forests, forests containing high concentrations of rare and endangered species, forests with high species endemism, core habitat for focal conservation species, and forests exhibiting rare evolutionary phenomena.

As with the landscape level components, it is important to consider the biodiversity components at multiple scales (i.e., global, regional, subregional, and local). Unlike the landscape components of Endangered Forest identification and mapping, however, biodiversity components require additional contextual information regarding such things as representation and population viability analyses, which are fundamental aspects of several biodiversity components.

4) Rare forest types (composition and structure)

Rare forest types are restricted in occurrence and extent at various spatial scales. Some forest types are naturally rare due to somewhat unusual and spatially restricted combinations of climate, topography, geology, soils, and other ecological factors. At the global scale, commonly cited examples of rare major forest types include Mediterranean climate forests (five regions worldwide), temperate rainforests (seven regions worldwide), Madagascar forests, and island forests (e.g., Hawaii, New Guinea, and parts of Indonesia). These forest regions are comparatively rare to other major forest types found around the world and many of these have been heavily altered by industrial human activity, making sites of reasonable quality highly valued for protection.

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[66] Ambuel, B. and S.A.Temple. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057-1068.
[67] Verboom, B. and R. Apeldoorn. 1990. Effects of habitat fragmentation on the red squirrel, *Sciurus vulgaris* L. Landscape Ecology 4:171-176.
[68] Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29:81-96.
[69] Rejmanek, M. 1989. Invasibility of plant communities. Pages 369-388 in Drake J.A., et al. (editors). Biological Invasions: A Global Perspective. John Wiley and Sons, New York, NY.

Under some circumstances, a forest's particular expression (e.g., structure or age) as opposed to its type or composition define its rarity. For example, the redwood forests of the U.S. west coast once covered approximately 700,000 ha.[70] Some of this region has been converted to other land cover since European settlement, but because of the commercial value of redwood, much of the region remains as redwood forest. Most rare in this region are high-quality (old growth) redwood stands, which have been reduced to only four percent of their original extent.[71] These stands possess high biodiversity values that are becoming increasingly rare in this ecoregion.

Scattered within other major forest types or surrounded by other major biomes are regionally or locally restricted forest types. The tropical cloud forests of the Americas and the pocosin forests of the Southeastern US are two examples. These have always been relatively rare, but as with the previous examples, they have been made rarer by industrial human impacts.

Another category of rare forests includes those forest types that were historically more widespread, but have been significantly reduced and degraded by human activity over time. For example, the longleaf pine forests of the U.S. southeast once covered over 40 percent of the region[72] but they have been reduced to less than 2 percent of their former range.[73]

Regardless of the scale of rarity, forest ecosystems should be identified and mapped according to recognized classifications. In some parts of the world (e.g., the United States) significant progress has been made. The Natural Heritage Program (NatureServe) currently maintains databases on rare plant communities. Whether they are mapped or not, forests of particular interest in this context include globally endangered to vulnerable communities (G1-G3) as well national or state endangered to vulnerable communities (N1-N3 or S1-S3).

5) Forests of high species richness (alpha and beta diversity)

Species richness is defined as "a simple measure of species diversity calculated as the total number of species in a habitat or community."[74] Biodiversity is not distributed randomly and it can be examined at various spatial scales. Diversity measured within a single habitat or community is sometimes referred to as ***alpha diversity***. Diversity measured among closely associated habitats or communities, usually associated with some environmental gradient, is termed ***beta diversity***, and diversity over large geographic areas is termed ***gamma diversity***.[75]

At the gamma diversity level, various regions of the planet have been identified as being ***biodiversity hotspots***. Conservation International has highlighted 25 forested and non-forested

[70] USFWS. 1997. Recovery plan for the marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, OR: U.S. Fish and Wildlife Service.
[71] Noss, R.F., et al. 2000. Conservation planning in the redwood region. In: Noss, R.F. (editor), The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, D.C.
[72] White, P.S., et al. 1998. Southeast. Pages 255-314. In: Mac, M.J., et al. (editors). Status and Trends of the Nation's Biological Resources. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey.
[73] Noss, R.F., et al. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biological Report 28. National Biological Service, Washington, DC.
[74] Fielder, P.L. and S.K. Jain. 1992. Conservation Biology: A Theory and Practice of Nature Conservation, Preservation, and Management. Chapman and Hall, New York, NY.
[75] Whitaker R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279-338.

biodiversity hotspots (see Appendix B, MAP 3). While such identified regions help conservationists focus their efforts globally, the biodiversity within them is typically not uniformly distributed. Indeed, upon closer examination, one would discover hotspots within hotspots. These hotspots reflect ***alpha and beta diversity*** patterns. This is also true of those forest ecoregions that are not globally recognized for their species richness; there are often concentrations of species at the subregional and local levels within most forest ecoregions that are of particular conservation importance.

Species richness (operating at the ***gamma diversity*** level) and species endemism (discussed later in this section) weighed heavily on World Wildlife Fund's determination of the most outstanding forested ecoregions.[76] Of all the forest ecoregions examined (522), over half (288) were identified as globally outstanding and under significant threat (Table 3; Appendix B, MAP 4).

Table 3. Summary of forest ecoregions and proportion identified as globally outstanding by World Wildlife Fund.

Major Biome	Number of Ecoregions	Globally Outstanding Number	Percent
Tropical & Subtropical Moist Forests	231	148	64
Tropical & Subtropical Dry Forests	59	27	46
Tropical & Subtropical Coniferous Forests	17	12	71
Temperate Broadleaf Forests	84	36	43
Temperate Coniferous Forests	53	21	40
Boreal Forests	28	9	32
Mediterranean Forests & Woodlands	50	35	70
Totals	**522**	**288**	**55**

Mapping forests with high species richness can be conducted in conjunction with mapping of the three levels of diversity. World Wildlife Fund, Conservation International, and others have adequately assessed gamma diversity from the global perspective with regions or ecoregions as the analytical mapping unit. Mapping areas of high species richness at the ***alpha and beta diversity*** levels within individual forested ecoregions is more challenging but equally important.

6) Forests containing high concentrations of rare and endangered species

Endangered and threatened species are generally listed by governments and receive varying levels of protection. Some governments concentrate primarily on the individual species, while some have provisions to protect not only the species themselves but also their critical habitat. The World Conservation Union's (IUCN) *Red List of Threatened Species* is one international source of information for globally rare and endangered species, but national and regional lists should also be consulted. Because of the way natural forests are impacted by human use, native species (plant and animal) are either eliminated or significantly reduced locally and regionally

[76] Ricketts T.H., et al. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press, Washington, D.C.

before the species becomes globally rare. The most effective conservation strategies should emphasize policy and management actions that keep common species common and prevent rare species from local/regional extirpation or global extinction. Throughout most of the world's forests, this ecological component focuses on those sites that contain high concentrations of rare or endangered species at the global, regional, and (under some circumstances) local levels. Under some circumstances, a single forest species may be so rare that its presence immediately elevates a particular forest's status to Endangered Forest. For example, in the neotropical forests of Columbia and Ecuador, an intact or remnant forest block known to contain the Banded Ground-cuckoo (*Neomorphus radiolosus*), a species of severely limited distribution which has been on the IUCN *Red List* since 1988,[77] would automatically be identified and mapped as an Endangered Forest.

7) Forests of high endemism

Endemic species are those organisms that occur within a narrow geographic range and exist nowhere else.[78] Centers of endemism are areas where many endemic species occur together. Species endemism is caused by geographic isolation and/or unusual habitats such as harsh physical environments, and therefore tends to be concentrated in localized habitats.[79] Because of this localization, they are often at high risk of extinction.

Endemism can be described for entire physiographic regions. For example, globally significant forest ecoregions for endemism include portions of Southeastern USA, Central Chilean forests, Indo-Burmese forests, Guinean forests of West Africa, and New Zealand forests. Although the global context is important, endemism is best mapped at intermediate spatial scales for the purpose of identifying and mapping Endangered Forests.

High species endemism is often positively correlated with high species richness, but these ecological considerations are very different and should be examined separately.

8) Core habitat for focal species (aquatic and terrestrial)

All preceding biodiversity components rely on community measures in one way or another. Although these are extremely helpful in determining what elements need to be examined in defining Endangered Forests, they are unable to define the appropriate quantity and distribution of landscape elements. Answers to these questions cannot be ascertained without considering the life history needs of individual species, and there are simply too many species to examine all of them efficiently. The challenge has been to find an effective way of meeting the needs for all species without examining each one individually. The concept of umbrella species has been proposed and used to address this issue. Umbrella species are "species whose requirements for persistence are believed to encapsulate those of an array of additional species."[80] It is widely

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[77] IUCN Red List species description. Available at: www.redlist.org/search/details.php?species=14536. (April 2005).
[78] Gentry, A.W. 1986. Endemism in tropical versus temperate plant communities. Pages 153-181, in Soule, M.E. (editor), Conservation Biology: The Science of Scarcity and Diversity. Sinauer Press, Sunderland, MA.
[79] Stebbins, G.L. 1980. Rarity of plant species: a synthetic viewpoint. Rhodora 82:77-86.
[80] Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11(4):849-856.

held by conservation scientists that for any given region one single umbrella species is inadequate, but a small number of species is achievable and can reasonably address the quantity and spatial configuration issues pertaining to regional conservation planning. These "***focal species***" are used to cover the breadth of forest landscapes and should include both terrestrial and aquatic species.

In the context of Endangered Forests, it is most important to identify and map existing critical habitat for the particular ***focal species*** chosen for each forest ecoregion. These species may or may not be rare and endangered. The most important criteria for selecting ***focal species*** for the Endangered Forest application include (1) dependence upon native forests during all or part of its life history, and (2) sensitivity to industrial use. Generating spatially explicit ***focal species*** viability models is a time-consuming and expensive undertaking. Therefore, mapping of critical ***focal species*** habitat should be carried out with the assistance of expert opinion using available forest habitat condition maps while predictive models are being generated.

9) Forests exhibiting rare ecological and evolutionary phenomena

In the context of Endangered Forests, rare ecological phenomena include conditions such as: (1) the presence of intact vertebrate faunas, including all predators; (2) extraordinary concentrations of animals (e.g., breeding and wintering habitat for mammals, birds, and butterflies); and (3) large-scale movement areas for animals (e.g., migratory bird stopovers or established migration routes).

Rare evolutionary phenomena include locations that display: (1) spectacular ***adaptive radiation*** within a taxon (e.g., honeycreepers in Hawaii); (2) high concentrations of unusual or unique higher taxa; (3) occurrences of primitive or relict communities; and (4) very high levels of beta diversity.

In places where the expressions of ecological or evolutionary phenomena are of global importance (e.g., Monarch butterfly wintering habitat in the forested mountains of Michoacan, Mexico), a single phenomenon alone could warrant Endangered Forest status. In other situations, the determination of Endangered Forests would be less straightforward. As with other ecological components, not every forest block that exhibits or contains rare ecological or evolutionary phenomena would automatically be identified as an Endangered Forest. Seasonal migration is an important part of the lives of many forest species (e.g., woodland caribou in Canada[81] and forest birds in Costa Rica[82]); however, the exact forest patches used are not necessarily the same from year to year, making it more difficult to pinpoint the location(s) of Endangered Forests. In these situations it is important to ensure that an adequate proportion of forest blocks in the proper spatial arrangement get the protection they need.

[81] Ferguson, S.H. and P.C. Elkie. 2004. Seasonal movement patterns of woodland caribou (Rangifer tarandus caribou). Journal of Zoology, The Zoological Society of London. 262:125-134.
[82] Blake, J.G. and B.A. Loiselle. 2000. Diversity of birds along an elevational gradient in the Cordillera Central, Costa Rica. The Auk 117(3):633-686.

Steps for Identifying and Mapping Endangered Forests

The previous review of landscape integrity and biodiversity components of Endangered Forests was intended to explain the major ecological considerations. Each of the components reviewed in this paper should be considered separately when identifying and mapping Endangered Forests, but they also need to be integrated together in a systematic fashion. As mentioned repeatedly throughout this document, the presence of a single attribute (or value) can be enough to warrant Endangered Forest status and protection, but in most cases, a combination of factors with reference to the regional context will be required to make this determination. To provide further guidance, we propose the following sequence of steps in order to assemble the various components in the identification and mapping of Endangered Forests. In various places (indicated below), ecoregional context and operational thresholds (based largely on ecology) are fundamentally important and will be necessary to assure consistency and replicability of independent efforts. The ten proposed steps are:

1. Map large landscape integrity building blocks – Intact Forest Landscapes [*ecoregional context and thresholds required*] and Remnant Forests and Restoration Cores [*ecoregional context and thresholds required*]

2. Describe biodiversity components in a spatially explicit fashion for Intact Forest Landscapes and Remnant Forests and Restoration Cores [*ecoregional context and thresholds required*]

3. Describe the range of relative conservation value based on the outcome of steps one and two in the context of **representation** [*ecoregional context and thresholds required*]

4. Map potential landscape connectivity

5. Assess threats (or stresses) to the native forests

6. Identify and map Endangered Forests

7. Define management prescriptions for each native forest area based on current conditions and stressors

8. Identify a small but ecologically meaningful set of indicators to help inform the efficacy of Endangered Forests in their local, regional and global contexts

9. Monitor these indicators over time

10. Adjust Endangered Forest status and/or management periodically as needed

These steps form an important foundation in a broader **conservation area design** process focusing on forested landscapes that is required to adequately balance protection, resource development, and restoration over space and time.

In all likelihood, a massive global mapping effort at the depth and breadth required to map Endangered Forests will not be possible due to budget and data constraints. We therefore propose existing assessments and tools be used to help prioritize where to map and at what scale to map based on considerations such as conservation value and level of threat (modified for mapping purposes by data availability). Using the relationship between conservation value and level of threat to prioritize actions is not a new idea in conservation science. Endangered Forests identification and mapping are most important in those regions that contain conservation values that are most irreplaceable at the global or ecoregional and most at risk of being lost (or of high vulnerability), especially as a result of industrial use (Figure 4).[83]

Essentially, irreplaceability is a measure assigned to an area that reflects its relative importance in the context of a planning domain (e.g., biome, ecoregion, or site) for achieving a set of regional conservation targets.[84] Vulnerability is defined as the risk a planning unit (e.g., intact forest landscape, remnant block, etc.) has of being transformed by extractive uses.[85] Figure 4 is being offered to help visualize the idea of priority setting, and it is important to point out that Endangered Forests are not restricted to Zone I; Endangered Forests can occur in all zones. We are only suggesting a mechanism for prioritizing which regions should be addressed to help assure important ecological values are not lost while the identification and mapping of Endangered Forests is carried out. The shaded area denotes the highest priority.

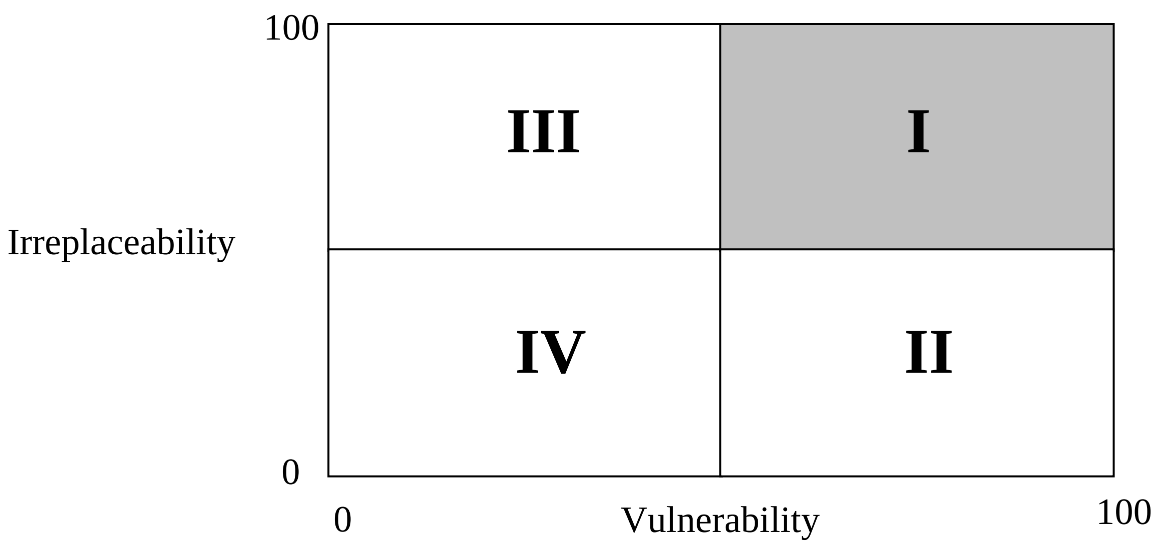

Figure 4. Irreplaceability and vulnerability diagram emphasizing the highest priority for addressing Endangered Forests (Zone I).

[83] Pressey, R.L., et al. 1994. Shades of irreplaceability: Towards a measure of the contribution of sites to a reservation goal. Biodiversity and Conservation 3:242-262.
[84] Cowling, R.M. and R.L. Pressey. 2001. Rapid plant diversification: Planning for an evolutionary future. Proceedings of the National Academy of Sciences of the U.S. 98(10):5452-5457.
[85] Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. Nature 405:243-253.

6. . RELATIONSHIP BETWEEN ENDANGERED AND HIGH CONSERVATION VALUE FORESTS

All forests have some conservation value, but some have such outstanding ecological values that they require full protection, while recognizing the legal and customary rights of indigenous and traditional forest peoples[86], from any intensive industrial use.[87] These are Endangered Forests. For years, conservation focused primarily on land allocation. For forests, most attention has been placed on the two extremes of a land allocation continuum—from protected parks or nature reserves on the one end to plantation forests on the other. However, this protection does not negate the full recognition and acceptance of the legal and customary rights of indigenous and traditional forest peoples to use their land for commercial and traditional uses[25 26].

According to the United Nations Environment Program, approximately 8 percent of the world's forests are in some form of legal protection.[88] Unfortunately, these protected areas do not cover the full range of forest types or characteristics— or the most productive sites. In many countries, large protected areas mostly represent "the lands nobody wanted."[89] For example, the largest protected areas in the U.S. and Canada are concentrated at higher elevations or in areas of low forest productivity.[90] However, many of the ecologically most important forests occur at lower

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[86] As defined by the Proposed American Declaration on the Rights of Indigenous Peoples (Approved by the Inter-American Commission on Human Rights on February 26, 1997), available from:
http://www.cidh.org/indigenous.htm
1. This Declaration applies to indigenous peoples as well as peoples whose social, cultural and economic conditions distinguish them from other sections of the national community, and whose status is regulated wholly or partially by their own customs or traditions or by special laws or regulations.
2. Self identification as indigenous shall be regarded as a fundamental criterion for determining the peoples to which the provisions of this Declaration apply.

[87] Indigenous peoples have rights to maintain and enjoy their cultures, their traditional ways of life; to own, develop, control, use and manage communal lands and resources traditionally owned or otherwise occupied and used by them; to represent themselves through their own institutions; to apply and enforce their customary law; to free and informed consent; and to full participation in decision-making. These rights are established in the International Covenant of Civil and Political Rights, the International Covenant of Economic Social and Cultural Rights and the Convention on the Elimination of Racial Discrimination. Available from: http://www.fern.org/pubs/reports/fear.pdf .

[25] As defined by the Proposed American Declaration on the Rights of Indigenous Peoples (Approved by the Inter-American Commission on Human Rights on February 26, 1997), available from:
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1. This Declaration applies to indigenous peoples as well as peoples whose social, cultural and economic conditions distinguish them from other sections of the national community, and whose status is regulated wholly or partially by their own customs or traditions or by special laws or regulations.
2. Self identification as indigenous shall be regarded as a fundamental criterion for determining the peoples to which the provisions of this Declaration apply.

[26] Indigenous peoples have rights to maintain and enjoy their cultures, their traditional ways of life; to own, develop, control, use and manage communal lands and resources traditionally owned or otherwise occupied and used by them; to represent themselves through their own institutions; to apply and enforce their customary law; to free and informed consent; and to full participation in decision-making. These rights are established in the International Covenant of Civil and Political Rights, the International Covenant of Economic Social and Cultural Rights and the Convention on the Elimination of Racial Discrimination. Available from: http://www.fern.org/pubs/reports/fear.pdf .

[88] United Nations Environment Program. 2005. Available at: www.unep-wcmc.org/forest/data/cdrom2/world.htm (April 2005).

[89] Shands, W.E. and R.G. Healy. 1977. The lands nobody wanted. The Conservation Foundation, Washington, D.C.

[90] Scott, J.M., et al. 2001. Nature reserves: Do they capture the full range of America's biological diversity? Ecological Applications 11(4): 999-1007.

elevations and on more productive sites, in conflict with economic uses. In addition, many protected areas are threatened by ineffective enforcement, and are in reality only "paper parks".

Most of the world's forests occur in the middle of the land allocation continuum: they lack strong, formal protections, but nevertheless support diverse ecological values along with economic uses. A compelling case has been made for emphasizing ecologically sustainable management of these remaining ***matrix forests*** as essential to maintaining biodiversity.[91] However, the Endangered Forests concept holds that there remains insufficient protection for most of the world's forests in light of the diverse threats discussed above, and that achieving ecological sustainability will require increasing the amount of protected forest as well as improved management of matrix forests.

The Endangered Forest concept offers a science-based approach for identifying those existing matrix native forests that deserve protection from industrial use. However, it is more than a reserve selection exercise. It examines Endangered Forests in context with other forest conservation and management approaches, such as sustainable forest management, while recognizing that forests of high ecological value can be protected in many different ways at many different scales (e.g., conventional parks, native lands, and forest management plans).

The concept of Endangered Forests has been developed amidst other initiatives to define ecologically important forests.[92] The Endangered Forest concept is intended to be brand-neutral, but is most frequently associated with ***High Conservation Value Forests*** (Principle 9) under the Forest Stewardship Council (FSC) forestry certification standard.[93] High Conservation Value Forests are forests that contain one or more High Conservation Value. The Forest Stewardship Council defines High Conservation Value Forests using six criteria that indicate forests with significant biological, environmental, and social values. The specific relationship between High Conservation Value Forests and Endangered Forests is shown in Table 2 and Figure 2. <u>In essence, Endangered Forests are those High Conservation Value Forests, or portions of them, that are so biologically distinct, rare, or ecologically important that industrial use would be incompatible with maintaining these values</u>**.**

Table 2. Relationship between Endangered Forests and High Conservation Value Forests.

Endangered Forest Components	**High Conservation Value Forests**
<u>Landscape Integrity Components</u> **1) Intact forest landscapes** Intact forest landscapes are dominated by native species, are largely maintained by natural processes, and are large enough to form functional core habitat leading toward viable populations of	**HCV2:** Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns

[91] Lindenmayer, D.B. and J.F. Franklin. 2002. Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach. Island Press, Washington, D.C.

[92] For example see: The Nature Conservancy (ecoregional assessments), Conservation International (biodiversity hotspots), World Wildlife Fund Canada (enduring features gap analysis), World Resources Institute (frontier forests), Greenpeace (ancient forest definitions), and IUCN-The World Conservation Union.

[93] Jennings, S., et al. 2004. The High Conservation Value Forest Toolkit. Edition 1, 2003. Proforest. Available at: www.fscoax.org/principal.htm (April 2004).

most native plant and animal species. **2) Remnant forests and restoration cores** Critical and/or intact forest fragments in heavily converted or ***degraded forest*** ecosystems able, with sufficient time for recovery, to become viable forest ecosystems. These are globally, regionally, or locally rare forests as a result of historical human activities. **3) Landscape connectivity** Remaining natural or restorable landscape level linkages between existing protected areas or other core natural habitats that target area-sensitive species and which maintain broader scale ecological processes (e.g., aquatic-terrestrial interaction, natural plant and animal dispersal, predator-prey interactions, and species migration).	of distribution and abundance. **HCV3:** Forest areas that are in or contain rare, threatened or endangered ecosystems.
<u>Biodiversity Components</u> **4) Rare forest types (composition and structure)** **5) Forests of high species richness (*alpha and beta diversity*) relative to their region** **6) Forests containing high concentrations of rare and endangered species** **7) Forests of high endemism** **8) Core habitat for *focal species* (aquatic and terrestrial)** **9) Forests exhibiting rare ecological and evolutionary phenomena**	**HCV1:** Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia). **HCV3:** Forest areas that are in or contain rare, threatened or endangered ecosystems.

Even though Endangered Forests should be off limits to industrial development, they may still require management – driven by conservation not economic imperatives - to protect their ecological values. In many cases (i.e., existing large, intact forest landscapes), little or no direct human intervention may be necessary; however, some areas will require active management to counter threats, such as controlling alien invaders or re-establishing natural disturbance regimes through prescribed fire or mechanical thinning.

At this time, the Endangered Forests concept focuses on the ecological components and do not include the aspects of High Conservation Values 4, 5 and 6 that pertain to human services.[94] These forest values may be endangered and therefore the forests may be classed "Endangered Forests", but they do not fall within the "/Ecological/ Components of Endangered Forests" treated in this document. Furthermore, identification of some of the important social values can only be adequately assessed through a consultative stakeholder approach.

[94] HCV4: Forest areas that provide the basic services of nature in critical situations (e.g., watershed protection, erosion control). HCV5: Forest areas fundamental to meeting the basic needs of local communities (e.g., subsistence, health). HCV6: Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic, or religious significance identified in cooperation with such local communities).

Endangered Forests are identified based on ecological components discussed in the previous section that are globally, regionally, or locally important. These ecological components can be landscape level features or biodiversity related. These components sometimes overlap and at other times are mutually exclusive. Any one component can be enough to identify a specific forest area as an Endangered Forest depending on the circumstance, but a full assessment of all of the ecological components is warranted. At this time, the most critical next step for Endangered Forests as well as for High Conservation Value Forests is the creation of regionally specific protocols or decision trees leading to consistent and defensible judgments for definition and mapping purposes. This will require a systematic application of multiscale contextual information and the establishment of meaningful ecological thresholds.

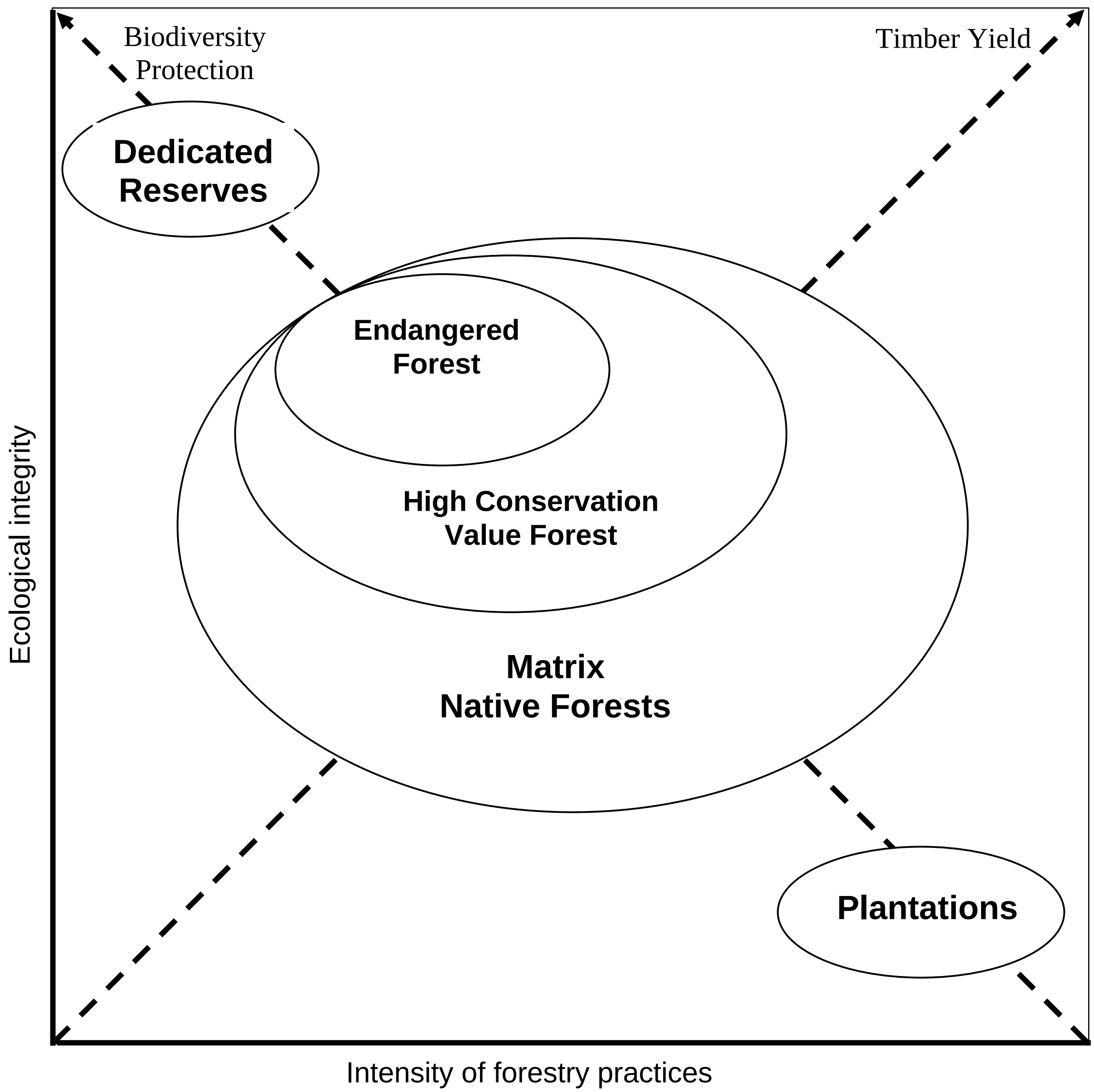

Figure 2. Diagram showing the relationship of Endangered Forests and High Conservation Value Forests in relation to the intensity of forest management continuum, timber yield, and biodiversity protection [Adapted from Lindenmayer and Franklin (2002)].

7. Major Considerations for Identifying and Mapping Endangered Forests

There are numerous overarching considerations still requiring attention in order to make the process of identifying and mapping Endangered Forests scientifically sound and technically operational. Major considerations for identifying and mapping Endangered Forests include the following:

- Spatially explicit data on the various components reviewed as well as other important themes (e.g., conservation status, historic land cover, and human disturbance data) are needed to map Endangered Forests reliably and consistently.

Conservation status in the form of designated protected areas is currently being mapped and monitored by the World Protected Areas Database Consortium as part of the IUCN (World Conservation Union) and United Nations Environment Program (UNEP). While this work is incomplete, the organizational infrastructure is in place, allowing for ongoing improvements in completeness and accuracy.[95]

Historic condition mapping has been completed for some areas of the world, but remains a data gap in others. Historic condition mapping is important in order to understand how dramatically humans have altered the extent, composition, and structure of forests through conversion and use. It provides extremely important historical context for defining appropriate conservation targets.

Continually monitoring human impacts (especially using remote sensing technologies) within forested ecoregions is important in defining and mapping Endangered Forests. There are numerous ongoing land cover change studies going on throughout the world (being conducted by government and by the conservation NGO community) that are important for understanding not only recent changes, but also in forecasting probable future conditions.

- Data themes used to identify and map Endangered Forests need to be applied at multiple scales – i.e., global, ecoregional, and local levels. Also, it will be important to generate results that will successfully translate between spatial scales and extents.

The concept of Endangered Forests is multifaceted and needs to be addressed using multiple spatial scales. Ecoregion-based assessments are convenient and ecologically meaningful[96] and are useful for addressing and summarizing endangered forest considerations. It is appropriate to

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[95] IUCN (World Conservation Union) and United Nations Environment Program (UNEP). 2004 World Database on Protected Areas. Available at: http://sea.unep-wcmc.org/wdbpa/download/wdpa2004/index.html (May 2004).
[96] Olson, D.M., et al. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.

address multiple spatial scales starting at the ecoregion level and working down to the more specific local level and, concurrently, to be able to integrate local level assessments (e.g., logging concession; political jurisdiction) and to work up the spatial hierarchy.

- A regionally differentiated approach is needed. Application of these definitions should reflect the ecological and socio-cultural diversity of the systems we seek to protect while also being unified under the same ecological and conservation biology components and principles.

- Global and regional map-based contextual information needs to be generated for the forested regions of the world in order to assure scientific rigor and consistency.

- A number of important ecological thresholds for each forest type and region must be determined and applied consistently.

- Science-based conservation planning is essential to articulating a strategy to attain ecological sustainability of forests.

To be effective, conservation plans must account for the relationship over time and space between forest protection, restoration, and industrial use. It is also important to note that effective conservation planning needs to be systematic, meaning it needs to be: (1) data-driven, (2) target-directed, (3) efficient, (4) explicit, transparent, and repeatable, and (5) flexible.[97]

- Certification or other planning processes should not delay Endangered Forest protection and special management.

- The topic of ecosystem services needs to be examined and integrated into the identification and mapping of Endangered Forests.

The focus of this document has been on the ecological components of Endangered Forests. However, one remaining important topic not fully addressed is that of ecosystem services. As described earlier in this document, ecosystem services can be categorized into four major types – Supporting, Provisioning, Regulatory, and Cultural. Two of these (Provisioning and Cultural) pertain exclusively to services provided to humans by nature, and while it is important to understand the limits to which natural systems can be pushed and still maintain these services, it has little bearing on the identification and mapping of Endangered Forests as it is being applied here. The identification of forests that should be protected because of their importance in providing services to humans can be assessed analytically to a degree, but an equally important aspect of that determination will require significant input from many groups and individuals.

The remaining two ecosystem service categories (Supporting and Regulatory), are equally important to both wild nature and humans, and it is primarily in these two service areas that more work is needed to determine how they might influence the identification and mapping of Endangered Forests. Determining which forests are critically important in terms of ecosystem

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[97] Cowling, R.M., et al. 1999. From representation to persistence: requirements for a sustainable system of conservation areas in the species-rich Mediterranean-climate desert of southern Africa. Diversity & Distributions 5(1-2):51-71.

functions such as nutrient regulation, local climate regulation, carbon sequestration, water purification, and hydrologic regimes is far more challenging than the nine ecological components presented in this document, but that does not mean these are unimportant.

8. CONCLUSION

This document was written to describe the scientific foundation for the concept of Endangered Forests and how it might be incorporated in identifying and mapping which of the world's remaining forests should be protected as part of a larger conservation strategy.

The technical planning issues surrounding this issue are numerous and complex and a measure of regional flexibility will undoubtedly be required to make meaningful progress on the ground. However, since global socio-economic forces are now driving the impacts on forests, it is extremely beneficial to address the technical aspects of planning for ecological sustainability of the world's forests by embracing an overarching conceptual framework that clearly articulates the ecological values that need to be actively addressed.

It is the intention of the authors this remains a "living" document, and incorporates advances in our understanding of forests and what is required to safeguard their ecological values. Conservation science, analytical methods, and data collection strategies are continuously evolving and improving over time, and all advances made must be integrated as needed. The important outstanding question of how to practically integrate the two ecosystem service categories described elsewhere in this document will have to be considered in future revisions. The authors recognize the need to periodically update and revise this document in order to reflect new information and other advances.

APPENDIX A GLOSSARY OF TERMS

Adaptive Radiation: the evolution of a species into many species that occupy diverse ways of life within the same geographical range.[98]

Alpha/Beta/Gamma Diversity: **Alpha diversity** - the number of species within a single local habitat or patch. **Beta diversity** - turnover of species between local habitats or patches. **Gamma diversity** - large area consisting of a number of habitats or patches.[99]

Biodiversity Hotspots: regions that harbor a great diversity of endemic species and, at the same time, have been significantly impacted and altered by human activities.[100]

Conservation Area Design: A conservation planning tool at multiple spatial scales that allows for the creation and exploration of land management scenarios relative to the following four goals

-Represent all native ecosystem types across their natural range of variation.
-Maintain viable populations of all native species in natural patterns of abundance and distribution.
-Maintain ecological and evolutionary processes.
-Ensure long-term and short-term resilience to environmental change.[101]

Degraded Forest: forest suffering from the loss of native species and processes due to human activities such that only certain components of the original biodiversity persist, often including significantly altered communities.[102]

Ecoregion: a large area of land or water that contains a geographically distinct assemblage of natural communities that (a) share a large majority of their species and ecological dynamics, (b) share similar environmental conditions, and (c) interact ecologically in ways that are critical for their long-term persistence.[103]

Ethnolinguistic Center: geographic origins of the world's peoples (particularly the world's indigenous, tribal and traditional peoples) differentiated by a unique language and culture.

Focal Species: consistent with the concept of umbrella species, a species or suite of species that can be used to develop explicit guidelines for determining the composition, quantity, and

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[98] Wilson, E.O. 1992. The Diversity of Life. Belknap Press, Cambridge, MA.
[99] Whittaker, RH. 1969. New concepts of kingdoms or organisms: Evolutionary relations are better represented by new classifications than by the traditional two kingdoms. Science. 1969 Jan 10, 163(863):150-160.
[100] Conservation International. 2003. Biodiversity Hotspots: What are hotspots? Available at: http://www.biodiversityhotspots.org/xp/Hotspots/hotspotsScience/ (May 2004).
[101] Noss, R.F. and A. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Washington, DC.
[102] Ricketts, T., et al. 1999. Terrestrial Ecoregions of North America. World Wildlife Fund – United States and Canada. Island Press, Washington, D.C.
[103] Olson, D.M., et al. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.

configuration of habitat patches at the landscape scale, which falls into one of four categories: area-limited species, resource -limited species, dispersal-limited species, or process-limited species.[104]

Fragmentation: the breaking up of a habitat, ecosystem or landscape into smaller, disconnected pieces.[105] Although natural disturbances fragment the landscape, human activities are also agents of fragmentation and are most important in the conservation planning context. Agents of fragmentation include roads, cleared lands, changes in land use, urbanization and other human developments.

Frontier Forest: large, relatively intact forest ecosystems. A ***frontier forest*** must – (1) be primarily forested; (2) be large enough to support viable populations of species associated with that forest type; (3) have its structure and composition are determined mainly by natural events; (4) contain primarily native species; and (5) be relatively unmanaged by humans.[106]

Gap Dynamics: a particular type of forest disturbance that is characterized by small- or micro-scale disturbance of the mature forest canopy. Trees die standing, snap off, or are blown to the ground, creating a "hole" in the canopy. The death of a single stem or a few stems releases available growing space. In time, this growing space is occupied by tree regeneration.[107]

High Conservation Value Forest: forest identified under Principle 9 of the Forest Stewardship Council. They are:
a) forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia); and/or large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance
b) forest areas that are in or contain rare, threatened or endangered ecosystems
c) forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control)
d) forest areas fundamental to meeting basic needs of local communities (e.g. subsistence, health) and/or critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).[108]

Home Range: the area in which an individual animal normally lives.

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[104] Lambeck, R.J. 1997. Focal species: A multi-species umbrella for nature conservation. Conservation Biology 11(4):849-856.
[105] Turner, M.G., et al. 2001. Landscape Ecology in Theory and Practice: Pattern and Process. Springer-Verlag, New York, NY.
[106] Bryant, D. 1997. The Last Frontier Forests: Ecosystems and Economies on the Edge. World Resources Institute, Washington, D.C. Available for purchase at: http://forests.wri.org//pubs_description.cfm?PubID=2619 (April 2004).
[107] McCarthy, John. 2001. Gap dynamics of forest trees: A review with particular attention to boreal forests. Environmental Review 9:1-59.
[108] Jennings, S., et al. 2004. The High Conservation Value Forest Toolkit. Edition 1, 2003. Proforest. Available at: www.fscoax.org/principal.htm (April 2004).

Intact Forest Landscapes: contiguous mosaics of naturally occurring ecosystems in a forest ecozone, essentially undisturbed by significant human influence and sufficiently large enough to be resilient to edge effects and to survive most natural disturbance events.[109]

Keystone Species: a species whose presence or activities support a large number of other species in the community (e.g., primary cavity nesters, herbivorous insects that outbreak).[110]

Landscape Linkage: large, regional connections between habitat blocks ("core areas") meant to facilitate animal movement and other essential flows between different sections of a landscape.[111] These linkages are not necessarily constricted, but are essential to maintaining connectivity function in the ecoregion.

Minimum Dynamic Area: the area necessary to ensure survival or recolonization of disturbed sites.[112]

Natural Disturbance Regime: the historic patterns (frequency and extent) of fire, insects, wind, landslides and other natural processes in an area.

Natural (Ecological) Resilience: the amount of change a system can undergo and still remain (1) within the same state or domain of attraction, (2) capable of self-organization, and (3) adaptable to changing conditions.[113]

Precautionary Principle or ***Precautionary Approach*****:** a response to uncertainty, in the face of risks to health or the environment. In general, it involves acting to avoid serious or irreversible potential harm, despite lack of scientific certainty as to the likelihood, magnitude, or causation of that harm.[114]

Representation: with reference to protected areas systems, representation refers to the protection of the full range of biodiversity of a given biogeographic unit within a system of protected areas (Ricketts et al. 1999).[115] To be ecologically effective, representation must be achieved in all ecosystems at all ecological spatial scales.

Roadless Block: that area bounded by a road, using the edge of the physical change that creates the road or the edge of the right-of-way, other ownership, or water, as a boundary. Minimum size of roadless blocks in forests depends on forest type. For example, in North America, a useful

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[109] Lee, P., et al. 2003. Canada's large intact forest landscapes. Global Forest Watch Canada. Edmonton, Alberta. Available at: www.globalforestwatch.ca (Aril 2005).
[110] Hannon, S.J. and C. McCallum. Using the focal species approach for conserving biodiversity in landscapes managed for forestry. Sustainable Forest Management Network Synthesis Paper, Alberta.
[111] Soulé, M.E., and J. Terborgh. 1999. Conserving nature at regional and continental scales - a scientific program for North America. BioScience 49:809-817.
[112] Pickett, S.T.A. and J.N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biological Conservation 13:27-37.
[113] Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecological Systematics 4:1-23.
[114] *Precautionary Principle Project, 2003. See www.pprinciple.net/the_precautionary_principle.html (May 2004).*
[115] Ricketts T.H., et al. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press, Washington, D.C.

roadless block definition is a 2,000 ha or larger forested block that has less than 0.5 miles of unpaved road per square mile, and no paved roads.[116]

Umbrella Species: a large, charismatic species (e.g., the Florida panther). When the habitat for such a species is protected, many other species will be protected as well.

APPENDIX B MAPS

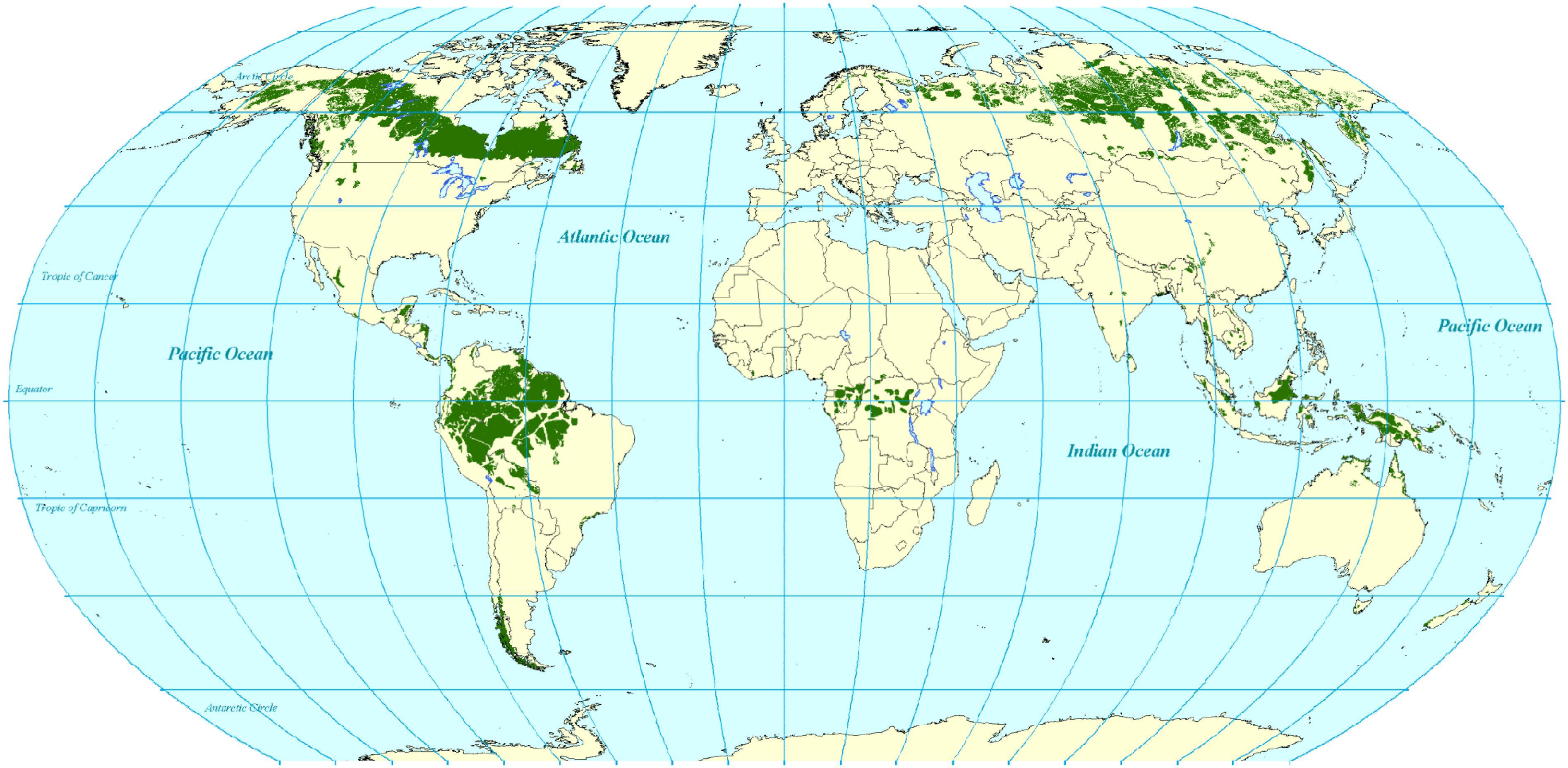
MAP 1. Frontier Forests as mapped by Bryant et al. 1997.

MAP 2. Intact forest landscapes for the boreal zone according to Global Forest Watch [Intact blocks - dark green = mature forest; light green = young forest/burned; yellow = non-forest/beige = non-intact boreal forest; gray non-boreal forest].

MAP 3. Conservation International's 25 Global Biodiversity Hotspots.

MAP 4. Biologically outstanding forest ecoregions as determined by World Wildlife Fund.

[116] Noss, R.F. 1992. The wildlands project land conservation strategy. Wild Earth (Special Issue) (Based on grizzly and elk habitat suitability.).



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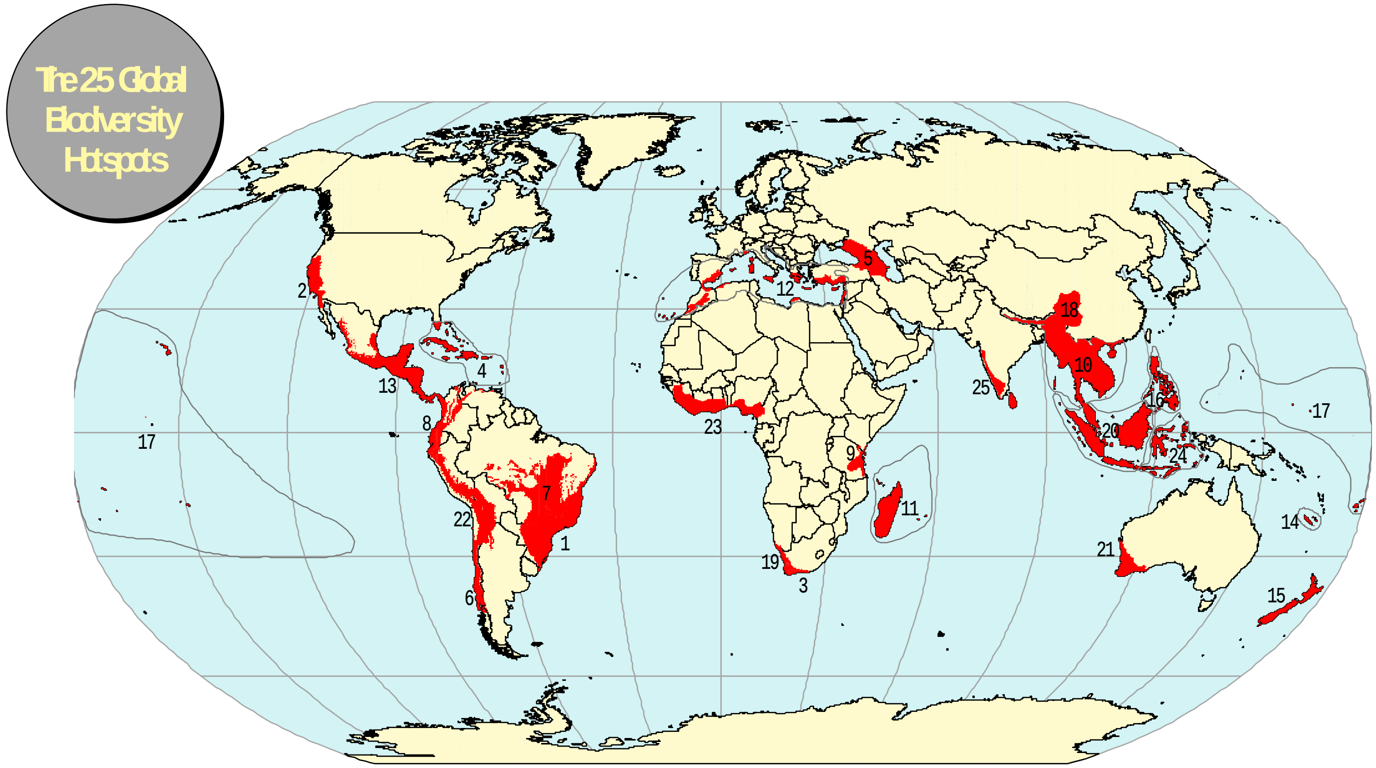
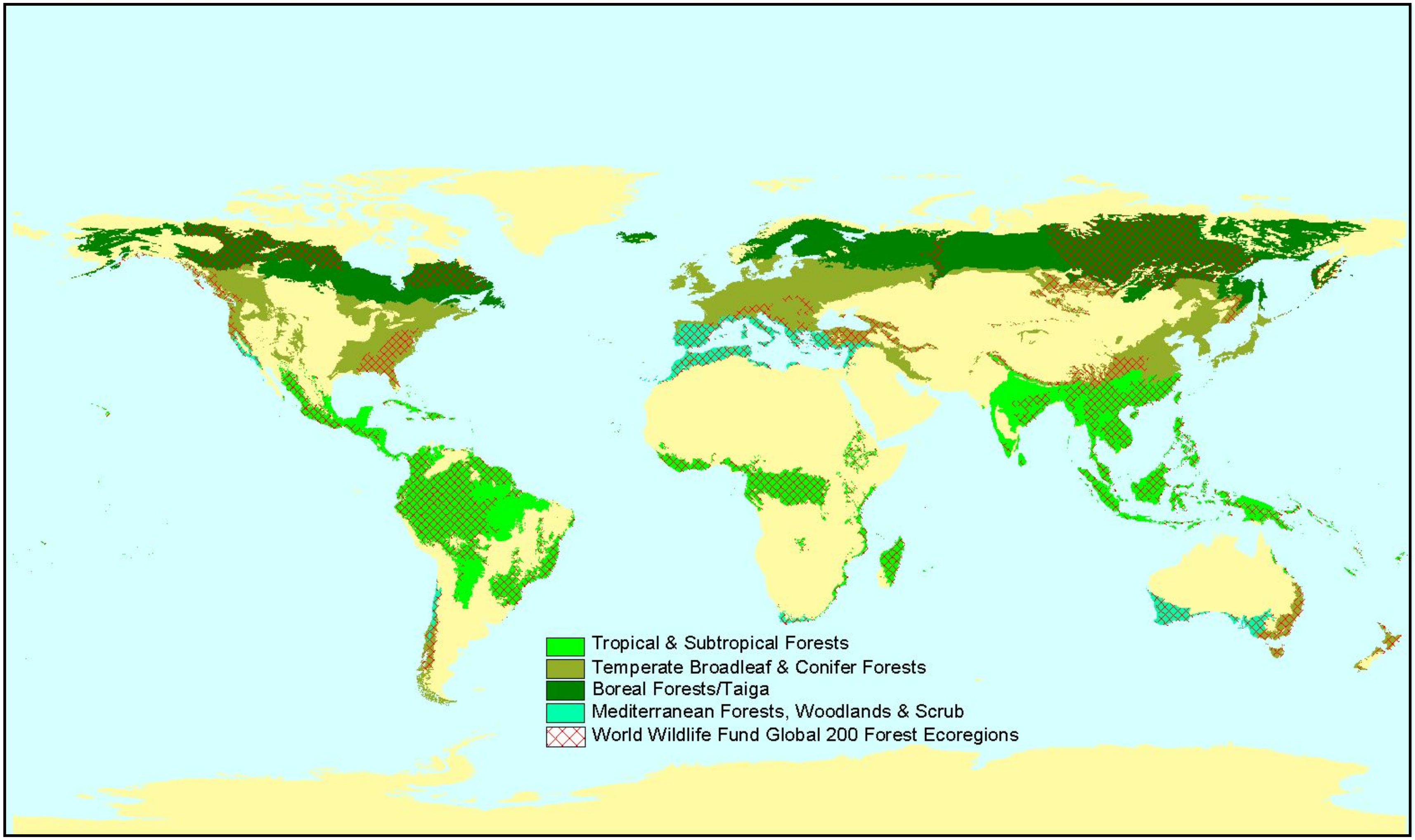


1. Atlantic Forest
2. California Floristic Province
3. Cape Floristic Region
4. Caribbean
5. Caucasus
6. Central Chile
7. Brazilian Cerrado
8. Choco-Darien-Western Ecuador
9. Eastern Arc Mountains & Coastal Forests
10. Indo-Burma
11. Madagascar & Indian Ocean Islands
12. Mediterranean Basin
13. Mesoamerica
14. New Caledonia
15. New Zealand
16. Philippines
17. Polynesia & Micronesia
18. Mountains of S. Central China
19. Succulent Karoo
20. Sundaland
21. Southwest Australia
22. Tropical Andes
23. Guinean Forests of West Africa
24. Wallacea
25. Western Ghats & Sri Lanka

source: Conservation International

MAP 3. Conservation International's 25 Global Biodiversity Hotspots.



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