Forests whose composition and structure largely reflect natural processes are known by various terms such as ancient, virgin, intact and old growth forest. We recommend “primary forest” as the preferred term as it is the most widely used internationally. The United Nations Food and Agriculture Organization’s (FAO) in its 2015 Forest Resource Assessment (FAO 2015) defined primary forest as:

“A naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.”

According to FAO (2015) primary forests have the following unique characteristics:

- Natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes;
- Sufficient geographic extent to maintain “natural characteristics;” and
- No known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become re-established.

The Secretariat of the Convention on Biological Diversity (SCBD 2001) states that a “primary forest is a forest that has never been logged and has developed following natural disturbances and under natural processes, regardless of its age”. SCBD further notes that "direct human disturbance" refers to “the intentional clearing of forest by any means (including fire) to manage or alter them for human use.” SCBD also clarifies that primary forests are “forests that are used inconsequentially by indigenous and local communities living traditional lifestyles relevant for the conservation and sustainable use of biological diversity.” The reference to indigenous people highlights that it is the intensity of human activity rather than the presence of people per se that matters most to the conservation of a primary forest.

Building on these definitions, the term “primary forest” describes natural forests that are:

- Largely undisturbed by industrial-scale land uses such as logging, mining, human-caused fires, and dam and road construction;
• Shaped by ecological and evolutionary processes including the full range of successional stages from young to old stands inclusive of the impact of natural disturbance regimes;
• More likely to possess the full complement of their evolved, characteristic plant and animal species with few if any exotics and invasives;
• Dominated by a largely continuous tree canopy cover, and
• Have unpolluted soil and deliver clean water.

**Key Attributes**

Considering the key attributes of primary forest that account for their ecological characteristics and ecosystem integrity can further refine the general definitions of primary forest.

1. **Landscape intactness**

At the bioregional and landscape levels, intactness generally refers to the extent to which a primary forest has been have fragmented by industrial land use, industrial extractive activity, roads, hydropower and other capital-intensive works. The term ‘intact forest landscape’ is used to describe an unbroken expanse of natural ecosystems within a zone of current forest extent that has not been degraded and fragmented by modern human land use and industrial activity (Potapov et al. 2008). In general, an intact forest landscape will be dominated by primary forests and retain the full complement of its characteristic native biodiversity. The vegetation structure and composition in these forests is largely the product of natural processes, including natural disturbance regimes such as wildfire, storms, insect outbreaks, and floods that can result in resetting forest stand succession to early seral stages.

There is no single threshold for delineating intact forest landscapes. The ecological and conservation significance of a given areal intactness threshold varies with the purpose of the study, climatic zone where the study is being undertaken, and landscape context in terms of natural gradients and land use history. A 50,000-hectare threshold has been used for global reconnaissance assessments (Potapov et al. 2008) and to formally define Intact Forest Landscapes (IFLs) (Potapov et al. 2008). Most IFLs are found in boreal and tropical forests. Within the temperate forest zone only about 3% of the world’s primary forest is in blocks >50,000 hectares, reflecting the extent to which these forests have been cleared and logged (Strittholt et al. 2006, Mackey et al. 2014, Lindenmayer et al. 2012, Mackey et al. 2015). Here, as in other highly fragmented and degraded forests globally, remnant blocks and patches of primary forest less than 50,000 ha play a vital role as wildlife habitats, restoration benchmarks, potential climate refugia, and core areas in protected area networks (Mackey et al. 2017). Landscape context is critical as an area of heavily disturbed forest embedded in a matrix of structurally and compositionally intact forest has significantly improved options for restoration (Chazdon 2003).

2. **Structural intactness**

At the stand or plot scale, structural intactness refers to the vertical vegetation structure measured in terms of canopy height, overstory tree cover, and canopy layering. Degraded forests typically have a simplified structure and often have a more open canopy and are dominated by younger and
smaller trees. At larger spatial scales, a primary forest will be mostly continuous across the landscape, though encompassing a mosaic of successional stages depending on the natural disturbance regime along with other ecosystem types associated, for example, with localised substrate or ground water conditions. Therefore, at this stand scale, structural intactness describes the degree to which the forest stand vegetation structure has been degraded by land use impacts. The structural intactness of primary forests means they strongly regulate microclimate conditions, increasing the resilience of ecosystem to fire events and buffering the impacts of temperature extremes and drought (Chen et al. 1999).

3. Biological intactness

Biological intactness refers to the extent to which the forest ecosystems are populated by native species that have evolved in and are characteristic of the ecosystem type and biome, including forest-dependent species and large apex predators. Various human impacts can result in the loss of native species and a decrease in biological intactness. Degradation at the stand and landscapes scales results in a loss of habitat conditions for dependent species, especially those that require forest interior conditions. Habitat loss and degradation together with over-use can result in local extirpation of dependent species, especially large mammalian predators, but also a wide range of seed dispersers from birds to small mammals. The absence of native species has significant implications for the adaptive capacity of a forest ecosystem due to the functional roles played by species in the ecosystem such as regulation of prey populations, pollination and seed dispersal (Peres et al. 2016, Harrison et al. 2013).

4. Connectivity

Forest ecosystems are not static objects but complex adaptive systems with dynamic ecological processes involving interactions between the biota and the physical environment and operating at a range a geographic and temporal scale. Forest ecosystems are therefore connected both internally and externally by a myriad of ecological processes. One example is the long distance movement of animals such as seasonal migrations of birds and butterflies. Another example, operating at the catchment scale, involves the hydro-ecological processes that maintain water quality and recharge soil profiles and aquifers vital for groundwater-dependent ecosystems (Soulé et al. 2007).

5. Bio-culturally integrity

Given the long association of indigenous peoples with primary forests (Nepstad et al. 2006), it is also necessary to acknowledge that forest landscapes vary in their bio-culturally intactness. Despite what has often been a long and often sorry history of colonisation, forests persist where the traditional custodial communities still reside along with their cosmology and sacred knowledge, beliefs and taboos that inform an ethical system, knowledge of natural history, including ecological relations of plants, animals, habitats, ecosystem dynamics, land and water resources, phytomedicinal compounds, climate, weather, natural resource use and management, cultural heritage such as oral histories, and practices such as rituals and ceremonies (Mackey & Claudie 2015).
It follows that intactness is not a single binary variable but rather represents a multi-dimensional gradient reflecting the increasing impacts of capital works such as roads and industrial land uses on the composition, structure and functions of natural forests. Various metrics of intactness have been developed, such as indices of wilderness quality based on measures of remoteness from urban settlements and modern infrastructure and the ecological impacts from industrial activity (Leslie et al. 1988).

There is convergence in the literature that wilderness areas are relatively large and intact landscapes (Kormos 2008, Watson et al. 2009). Wilderness areas that are dominantly forested, whatever the areal thresholds selected for their delineation, are therefore synonymous with intact forest landscapes. For instance, to identify wilderness areas of global significance, Mittermeier et al. (2003) specified three wilderness quality criteria and thresholds: (a) minimum size of 10,000 km² (1,000,000 ha); (b) sparsely populated with ≤5 people per km²; and (c) relatively intact with ≥70% of primary habitat remaining on an ecoregion basis. However, it should be noted that intact areas this large are no longer possible in many regions such as the contiguous U.S. and Europe (Heilman et al. 2002). In the U.S. forest roadless areas >2,000 ha have been recognized in forest policies for their special natural values.

6. Stand age and seral stage

In the scientific literature, the term ‘primary’ refers to both (i) natural forests largely undisturbed by industrial-scale land use and (ii) a stand of natural forest that has passed through seral stages and has reached late successional stages (this can be defined as when forest growth begins to level off – cumulative mean annual increment – along with older forest structures such as snags, vertical layering, and coarse woody debris). In most forest ecosystems, species with specialized life history traits occupy different successional stages in development following natural disturbance such as the death of canopy trees that create gaps in the dominant overstory. Typically, fast growing plants and shorter-lived tree species dominate gaps, followed by slowly growing longer-lived ones that tolerate shaded environments (Chazdon et al. 2010). Intact forest landscapes are usually dominated by late successional, primary forest patches with a scattering of patches representing younger seral stages created by natural disturbance events overtime. In temperate primary forests, natural fire regime play role in maintaining the full suite of seral conditions at large spatio-temporal scales (DellaSala & Hanson 2015).

While ‘old-growth’ is a commonly used term for primary forest, there is no generally agreed definition of old growth or age of trees because age varies with site, regional and biome specific factors. While many primary forest trees are long lived (300-1,000 years; Viera et al. 2005), old growth is generally defined according to the presence of specific forest structures including large, older trees, snags, coarse woody debris and canopy layering that take decades to centuries to acquire (Lindenmayer et al. 2013).

Given sufficient time (i.e., centuries) and depending on the scale and intensity of disturbance, forests that are disturbed by human activities in the past may naturally regain many of the features that characterize primary forests while others will require restoration. It is also possible for logged and otherwise disturbed secondary forest to contain some mature (“legacy”) trees and other
structures retained by loggers and if present these can speed up succession to an ecologically mature forest state.

7. Geographic extent

There is no simple answer to the question of what is the minimum size for a forest, let alone that of a primary forest. We tend to define ‘large’ and ‘small’ by reference to human dimensions. Natural processes operate at different scales – sometimes very slowly over centuries and requiring very large areas – hundreds of thousands of hectares or more. Furthermore, certain natural features are only apparent at specific scales. Thanks in no small part to satellite imagery, we have an increasing appreciation of the range of geographic and temporal scales at which species, ecological communities and ecosystem processes operate, the emergence of different ecosystem properties at different scales, and the complex myriad ecological connections that promote resilience (Levin 1992).

Most field surveys undertaken by ecologists and foresters occur at the stand-level that is typically sampled in a quadrant ≤1 ha⁻¹ (100 x 100m). Conventional stand level perspectives of forest management have influenced international definitions of forest that are typically defined in terms of a minimum area, canopy height, and canopy density that range from 0.01 - 5 ha minimum area, 2.5 - 10 m minimum height, and 10-30% minimum canopy cover (FAO 2010, FAO 2012, UNFCCC 2005). At this fine spatial scale, primary forests can be distinguished by the intactness of the vegetation structure in terms of canopy height and cover, the number of vertical layers, and the richness of plant growth forms.

From a conservation perspective, the stand scale does not entail key ecological and evolutionary features that become apparent and operate at larger geographic extents. Under natural conditions, primary forest at the landscape scale will encompass a diversity of forest ecosystems types and seral stages. The bioregional scale (>100,000 - ~1,000,000 ha) is needed to consider larger scale processes such as migratory species, apex predators, and watershed hydrology. The larger the extent of a forested landscape, the more likely we are to find heterogeneity due to the diversity of edaphic and topographic conditions and the history of natural disturbance regimes (Gill 1975).

Natural disturbances such as fire, floods and tropical storms, vary in their type, seasonality, spatial scale, intensity, frequency and duration and are part of all natural ecosystem dynamics (Gill 1975; Angelstam 1998). Vegetation that has been disturbed by and is recovering from natural events are still part of primary forest provided when nested within a larger unperturbed extent supporting viable populations of the characteristic biota. The fact that primary forests entail a diversity of types and conditions allows for the small-scale disturbance by indigenous forest dwelling communities.

References


