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This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Chiarucci A., Piovesan G. (2020). Need for a global map of forest naturalness for a sustainable future. CONSERVATION BIOLOGY, 34(2), 368-372 [10.1111/cobi.13408].

Availability:

This version is available at: <https://hdl.handle.net/11585/786265> since: 2021-01-10

Published:

DOI: <http://doi.org/10.1111/cobi.13408>

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Need for a global map of forest naturalness for a sustainable future

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Running head: Measuring forest change

Keywords: conservation, forest biodiversity, forest functioning, mature forests, old-growth forests, deforestation, rewilding

Article impact statement: Forest status assessments are biased toward tree cover and do not sufficiently consider bio-ecological properties; a global map of forest naturalness is needed for a sustainable future.

Abstract

There is a growing need to assess and monitor forest cover and its conservation status over global scales to determine human impact on ecosystems and to develop sustainability plans.

Recent approaches to measure regional and global forest status and dynamics are based on remotely sensed estimates of tree cover. We argue that tree cover should not be used to assess the area of forest ecosystems because tree cover is an undefined subset of forest cover. For example, tree cover can indicate a positive trend even in the presence of deforestation, as in the case of plantations. We believe a global map of forest naturalness that accounts for the bio-ecological integrity of forest ecosystems, for example, intact forests, old-growth forest patches, rewilding forests (exploited forest landscapes undergoing long-term natural dynamics so they can become the old-growth forest of the future), and managed forests is needed for global forest assessment.

Tracking forest decline and recovery

The protection, restoration, and sustainable use of forests are key targets in achieving the goals of the UN 2030 agenda. Monitoring global dynamics of forest cover relative to natural and anthropogenic drivers is challenging and represents a major priority for assessing sustainable development. Curtis et al. (2018) classified and monitored for the first time the most important drivers of global forest ecosystem loss and degradation and found that about 5 million ha of tree cover are lost yearly because of commodity-driven deforestation. Song et al. (2018), using 34 years of remotely sensed data and a methodological approach similar to Curtis et al.'s (2018), analyzed global changes in land cover and found that “contrary to the prevailing view that forest area has declined globally (e.g. FAO [Food and Agriculture Organization of the United Nations] reports), tree cover has increased by +7.1%.”. This surprising greening trend reported by them and others is due to an increase in tree cover within the range of major forest biomes outside the tropics that outweighs global deforestation. These positive land-cover changes are associated with an expansion of

agricultural lands, forestry, and urban area. The positive greening trend leads to the perception that global changes in forest area and condition can be measured with tree cover. Such a conclusion is dangerous from an ecological and conservation perspective because it can be misused by politicians to state that world forests are increasing.

Tree cover versus forests

The idea that tree cover and forest are synonymous is rooted in the definitions of *forest* applied in forest mapping and tree-cover mapping. From the point of view of ecologists, lands with tree cover are not always forests, but in other contexts *tree cover* and *forest* are used interchangeably, which could mislead policy makers. In remote-sensing studies, tree cover is widely used to estimate forest area at global and regional scales. The problem of separating forests from other land-use classes dominated by cultivated trees has been known for a long time (Pekkarinen et al. 2009), and this problem affects most of the global and regional forest maps derived from remotely sensed data (e.g. McDicken 2015). Song et al. (2018) used a simple land classification system that recognizes tree canopy, short vegetation, and bare ground, but it can only be used to measure tree cover, not forests. The difficulty of properly identifying trees within forests as separate subjects is related to perception and psychology (Cavanagh 2001; Nijboer, 2008), and we argue that identifying forests within different types of tree cover is similarly difficult, but essential to forest conservation.

Tree-cover data cannot be considered a direct indicator of forests for several reasons that are based in the features of forest ecosystems. First, forest area is clearly a subset of tree-cover area, but its proportion may decrease considerably as the intensity of human activity (e.g., tree cover under agriculture and urban land use) increases. Figure 1 reports examples of tree-covered area that is clearly not forest. An ecologist or a conservation scientist would never

categorize an orchard or a poplar plantation, as forest. Global estimates of the area of tree-canopy cover (Hansen et al. 2013) are 19% higher than the area estimated to be covered in forest (Lindquist et al. 2012) or even 23% higher in dryland biomes (Bastin et al. 2017).

Reducing forest monitoring to the simple collection of tree-cover data can represent a step backward for sustainable forest management policy, with respect to the FAO reporting, because it merges the area of lands with tree plantations in agricultural production systems (excluded from the FAO FRA-2015 forest definition) with that of forest ecosystems. Clearly, this is not the optimal way to monitor the amount of forest and may lead to misleading assessments for sustainable environmental policy.

On the other hand, The FAO defines *forest ecosystems* simply as a land-use category, and this is likely to be conceptually inadequate to meet the challenges of forest conservation and sustainability. The FAO definition includes fragmented (0.5 ha low-end threshold), highly affected, degraded forest lands (clearcuts and stands with very low canopy cover 10-50%), and unforested area (e.g., roads, firebreaks, Christmas tree plantations).

Facing complex problems in search of a solution

We see the global mapping of forests with their bio-ecological values and functional status as a major, urgent task for conservation and sustainable development. To determine whether forested area is increasing or decreasing, the term *forest* needs to be clearly defined with respect to conservation goals. In global forest mapping, *forest* is usually defined in terms of tree cover, and this is a limitation because in fragmented and degraded forests ecosystem function and services are impaired and that makes them different from fully functional and ecologically valuable forests (Chazdon et al. 2016). However, the FAO forest resource

assessment merges degraded forest stands with functional forest ecosystems, whereas degraded lands and soils should be mapped separately for evaluating sustainable development goals (see SDG indicator 15.3.1; United Nations 2017). Another problem arises from the misclassification of open forest ecosystems when a tree-cover or FAO approach is used (Griffith et al. 2017). This misclassification undermines conservation goals when, for example, tree densification in steppes and savannas are a consequence of human-driven fire suppression, which affects natural-disturbance dynamics.

Tree-cover variations only partially capture the distribution and function of complex forest ecosystems because the latter depends on structural (e.g., structural complexity, natural vs. artificial regeneration, deadwood amount) and compositional (e.g., species composition, species identity) features. Therefore, using tree-cover data does not quantify forest functions and dynamics well and is not enough to provide essential moreecological information on forests. For example, Global Forest Watch's (www.globalforestwatch.org) (Hansen et al. 2013 www.globalforestwatch.org), tree-cover map is globally consistent, because it is based on satellite data, but it does not identify or trace functional forest ecosystems.

Forest ecosystems are characterized by complex interactions among trees, soil, flora, fauna, and microbiota, and their provision of ecosystem services should be recognized, especially in the case of intact forests (Watson et al. 2018). Time since last major disturbance is another relevant factor in forest ecology because old-growth forests once lost will require centuries for restoration (Fig. 2). Curtis et al. (2018) developed an interesting innovation to classify drivers of forest disturbances, but forest ecosystems should be categorized separately from lands with artificial tree cover. Tracing natural forest disturbances is undoubtedly a relevant task for biogeochemical studies. Moreover, preserving and restoring forest landscapes and their natural disturbance regimes is a key and urgent goal for biodiversity conservation

(IPBES 2019; Lovejoy 2019). In temperate and tropical rainforest biomes, late-successional old-growth stages are a dominant component of the potential vegetation (Fig. 2), but in other biomes, such as the taiga, stand-replacing disturbances (mostly wildfire) at multidecadal to centennial time frames (e.g. 100 y) are the norm (Macias Fauria and Johnson 2007; Ali et al. 2012). Systems of global forest monitoring should track natural forested areas and map naturally disturbed patches within a forest as part of demarcating the functional ecological integrity of forest ecosystems (e.g. Swanson et al. 2011). In this perspective, the loss of forest cover caused by natural disturbance (e.g., wildfire, avalanches) should not be interpreted negatively since it represents a natural disturbance process; remark the presence of natural processes, ; in contrast, disturbances related to human activities, such as fires and logging, should be assessed separately as potential processes of forest degradation .

Recognizing differences in disturbance regimes is fundamental to reconciling global-forest estimates and country reporting of anthropogenic forest CO₂ sinks (Grassi et al. 2018) and to revealing decisive targets in carbon mitigation strategy (Erb et al. 2018).

Undoubtedly, the Global Forest Watch platform has improved transparency and accountability in forest management and conservation (Hansen et al. 2013) and this online platform continually makes interesting improvements. We recognize that sophisticated approaches are still needed to map and assess the functional complexity of forest ecosystems at the global scale (Schneider et al. 2017). Data on biodiversity and functional traits should be integrated with remote-sensing information (Bush et al. 2017) to provide sound models of global change and to inform policy makers that ecosystem services are dependent on complex bioecological interactions.

Mapping forest naturalness as a first step

We believe the first fundamental step for robust monitoring of real forest is the production of a global map of intact forests (Potapov et al. 2017; Watson et al. 2018) and old-growth forest patches (Frelich 2002). Forest takes a long time to recover, and as a result of global change the decrease in intact forests can only continue. Positive trends in forest cover may exist, but in the short term (decades) they are most likely to be limited to early-successional stages and, as such, they should be monitored separately from intact and old-growth forests. Outcomes, such as those reported by Song et al. (2018), that provide a positive message on global forest status without mentioning the problem of conserving intact forests can be extremely dangerous. Alarming results are coming from other research. Potapov et al. (2017) report a 7.2% global decrease in intact forest since 2000. Similar claims can be made for boreal forest ecosystems (Svensson et al. 2019). This highlights the need to monitor forest intactness and to protect forest function because many forest ecosystems – such as tropical forests - are likely to approach a breaking point (Taubert et al. 2018). Identifying old-growth forests with high conservation value in terms of, for example, naturalness (Di Filippo et al. 2017) or continuity (McMullin and Wiersma 2019), is crucial for preserving biodiversity and ecosystem functioning and is a challenging target for sustainable development (Jones et al. 2018a; 2018b). Mapping, monitoring, and preserving intact forests and old-growth stands worldwide is a priority task because of their unique function in biodiversity conservation and role in mitigating climate change (e.g. global fluxes). For all these reasons the area of intact forests, such as that of unexploited tropical forest lands or old-growth temperate forests, cannot be merged into a global picture of tree cover that includes plantations or other artificially tree covered areas.

The time is right for developing a global map of forest naturalness in the major ecosystems of the world. Forest growth and recovery is slow with respect to the human time scale, and successional stages belonging to mature and old-growth forests do not change in decades

(Frelich 2002). Moreover, full recovery of species compositions and complex structure take centuries (Rozendaal et al. 2019). So, the scientific community could produce a worldwide forest map of forest naturalness based on specific, measurable, achievable, realistic, and time bound criteria (Green et al., 2019) in which areas subject to prevailing anthropic drivers, such as plantations and managed forests, are mapped separately from areas subject to prevailing natural drivers, such as intact and, old-growth forests or exploited forest landscapes undergoing long-term natural dynamics so they can become the old-growth forest of the future (ecological rewilding; Navarro and Pereira 2012; Perino et al. 2019). Forests subject to prevailing natural drivers represent the best reference to evaluate the implementation of environmental policy for conservation while forest landscapes that are relatively undisturbed by humans are expected to decline continuously in the near future or, in the best case, to stabilize. In the long-term, a reversal of this decline would be the best indicator of sustainable forest development.

Acknowledgments

We thank S. A. Mensing for comments on early version of the manuscript and Marisa Ceccarelli for creating Fig. 2. G. Piovesan carried out this research in the frame of the MIUR (Ministry for education, University and Research) initiative Department of Excellence (Law 232/2016).

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Figure 1. Examples of tree cover in Mediterranean and temperate regions that cannot be considered forest because they are under intensive agriculture systems: (a) olive grove (G. Piovesan); (b) popular plantation (photo by Jonathan Billinger and licensed for reuse under this Creative Commons License) , (c) hazelnut and walnut plantation (G. Piovesan); and (d) dehesas (Wikimedia Commons).





Figure 2. (SSG about contents of figure legends) Illustration - drawn by Marisa Ceccarelli - of forest succession in a temperate region. From left to right: grassland to pioneer communities (low carbon stock, conservation relevance depends on whether disturbance is natural or anthropogenic) are replaced by late-successional old-growth (OG) stand with natural gaps in the canopy (high carbon stock, resilient to climate change and fires, important for conservation).