TECHNICAL COMMENT

FOREST ECOLOGY

Comment on "The extent of forest in dryland biomes"

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Bastin *et al*. (Reports, 12 May 2017, p. 635) infer forest as more globally extensive than previously estimated using tree cover data. However, their forest definition does not reflect ecosystem function or biotic composition. These structural and climatic definitions inflate forest estimates across the tropics and undermine conservation goals, leading to inappropriate management policies and practices in tropical grassy ecosystems.

Bastin *et al.* (*1*) used high-resolution Google Earth images to estimate tree canopy cover in 213,795 globally distributed 0.5-ha plots. Extrapolation of these plot-level data produced a forest cover classification from which they concluded that "dry forests" cover ~40% more of the global land area than previously estimated, increasing global forest cover estimates by 9%. However, their calculation of forest extent is based on a structural definition adopted by the Food and Agriculture Organization of the United Nations (FAO), where areas greater than 0.5 ha and with more than 10% tree cover are considered forest (*1*). As a consequence of applying the FAO forest definition, Bastin *et al.* (*1*) misclassify as dry forest many tropical regions that are in fact savannas. Savannas differ from forests in having a continuous grassy ground layer that supports fire and grazing mammals. These disturbances select for functionally distinct plant traits and communities that are different from forests in their biodiversity and ecosystem services (*2*, *3*). Bastin *et al.* (*1*) refer to plots with 10 to 40% tree cover as open forest and plots with >40% tree cover as closed forest. These "forest" classes clearly overlap with savannas, which can range in tree cover from 0 to 80% (*4*). Tree cover has been previously demonstrated as an unreliable metric by which to differentiate forest and savanna (*3*), and sites classified by Bastin *et al.* (*1*) as forest include iconic savannas such as Kruger National Park (Fig. 1). Additionally, the FAO "forest" definition applied by Bastin *et al.* (*1*) includes sites where tree cover is "temporarily under 10% but is expected to recover," an unclear guideline implying degradation rather than accounting for known temporal variability in savanna tree cover (*5*–*7*). Consequently, the majority of "new" forest identified here resulted from the misclassification of tropical savannas as "forests" (figure S12 of Bastin *et al.*) (*8*).

The implications of misclassification of savanna as forest include support for afforestation, modification of mammalian grazer and browser regimes, and fire suppression policies (*9*), as fire and large herbivores are generally considered to be at odds with the integrity of forest ecosystems (*2*, *10*, *11*). In contrast, it is the loss of these processes in many savannas that results in their degradation (*8*). Over millions of years, fires and herbivores have driven the evolution of herbaceous plants with belowground buds, underground trees, and trees with thick insulating bark—traits that make savanna species functionally distinct from forest species (*5*, *9*). Afforestation and fire suppression policies in savannas risk destroying a wealth of specialized and endemic savanna biodiversity that underpins unique ecological processes, as well as compromising ecosystem functions such as carbon cycling and water and energy exchange (*5*, *6*, *9*, *11*, *12*). Further, afforestation strategies have a negative impact on grassy ecosystem function by altering the hydrology and/or trophic structure (*2*, *8*) of entire landscapes. Many of the sites identified by Bastin *et al.* (*1*) as forest fall within areas identified as opportunities for "forest and landscape restoration" (*6*), increasing the very real risk that misclassification could misdirect afforestation policies (*8*).

Further underlying the misclassification of savanna is an assumption that biomes can be delineated using a single simple metric of climate (i.e., aridity index). Using a threshold aridity index (0.65) belies the rich ecological complexity in identification and characterization of biomes, the subject of debate for a century [reviewed in (*13*)]. Historical contingencies in the distribution and evolution of plant lineages and their associated functional traits generate critical biogeographic variation in the limits of biomes and their dynamics in response to climate (e.g., savannas across continents) (*14*). Because of this complexity, the climate threshold in Bastin *et al.* (*1*) also misclassifies some wet neotropical forests (in Amazonian Ecuador and Peru, and on the Pacific coast of Ecuador and Colombia) as dry forest (*15*). Recent evidence overwhelmingly shows that definitions of forest based solely on tree cover or climate thresholds ignore key functional differences between closed- and open-canopy vegetation types (*2*, *3*, *6*, *8*).

Many of the ecosystems identified by Bastin *et al.* (*1*) are not forest but savannas (*3*, *5*) where low tree cover is the result of natural processes (*4*, *5*, *8*, *9*). Their aim was "to accurately determine how much forest and tree cover remains in dryland biomes" (p. 635). This aim implies that dryland systems were once widely forested, which is incorrect. In Fig. 2, we map locations derived from (*5*) providing fossil evidence that many "forest" sites in Bastin *et al.* (*1*) have supported tree-grass mosaic vegetation over millennia. Conservation policies should reflect savanna antiquity and not equate low tree cover with degradation. Moreover, although we have focused on savannas, the inflation of forest extent could equally hamper conservation in other threatened forests. An example is the dry forests of Latin America, which lack adequate protected areas to

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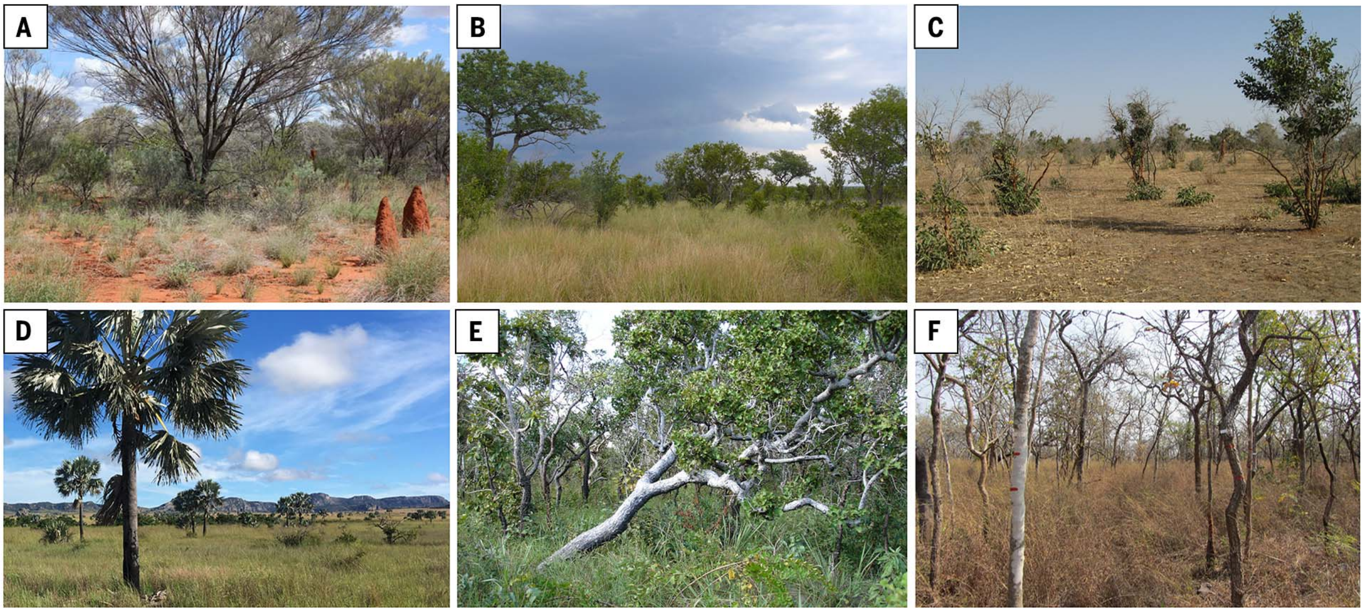

Fig. 1. Examples of savannas, with continuous grass layers and discontinuous tree canopies, that are misclassified as forests by the FAO 10% tree cover threshold in Bastin *et al.* (**A**) *Acacia*-grass mixture from Australia, functionally a savanna according to contemporary ecological understanding. This is figure S3 from Bastin *et al.* (*1*). (**B**) *Combretum* savanna in Kruger National Park, South Africa. (**C**) South Sahel site in Lakamané, Mali. This site has ~12.4% tree cover, is heavily grazed, and experiences frequent fires. (**D**) Savanna from Isalo National Park, Madagascar. (**E**) Savanna (cerrado) in eastern lowland Bolivia. This site is within the "dry subhumid" zone in Bastin *et al*. and experiences frequent fires. (**F**) Long-term monitoring plot in an *Anogeissus-Terminalia-Chloroxylon* savanna in Amrabad Tiger Reserve, southern India.

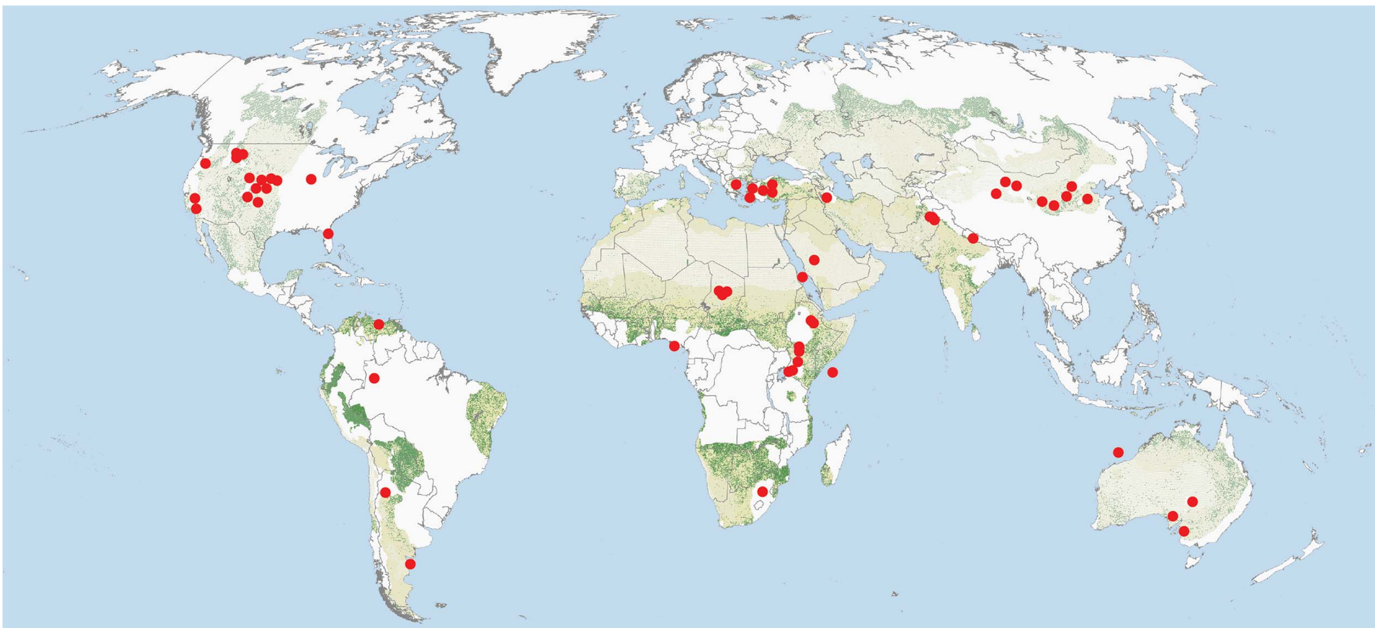

Fig. 2. Fossil evidence for vegetation containing mixes of trees and grasses. Forest distribution (green) in "drylands," from Bastin *et al*., overlain by points (red dots) where fossil evidence (e.g., fossil floras and faunas, stable carbon isotopes) demonstrates past occurrence (>0.5 million years ago, but mainly 4 million to 22 million years ago) of grass-dominated habitats and their faunas across continents (*5*). Although savanna extent has shifted with changing climates and disturbance regimes, and although exact compositions have changed during the past 22 million years, it is abundantly clear that these regions have deep evolutionary roots as mixed tree-grass ecosystems (*5*). Ocean points represent paleovegetation data reconstructed from marine cores.

safeguard their unique and geographically heterogeneous flora (*15*). Although the data collected by Bastin *et al.* (*1*) are impressive and potentially useful, the use of the FAO forest definition is damaging to conservation goals across the tropics.

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