Data Submitted (UTC 11): 8/26/2022 4:00:00 AM
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Comments: Request for Information on defining Old-growth and Mature Forests on Federal Lands
On July 15, 2022, the U.S. Forest Service and Bureau of Land Management announced a request for information on defining federal old-growth and mature forests on federal land. This request is aligned with Executive Order 14072. Specifically, the services request information on: criteria for a universal definition framework that motivates mature and old-growth forest conservation for planning and adaptive management; overarching old-growth and mature forest characteristics that belong in a definition framework; how a definition can reflect changes based on disturbance and variation in forest type/composition, climate, site productivity, and geographic region; how a definition can be durable but also accommodate and reflect changes in climate and forest composition; and what, if any, forest characteristics should be excluded in a definition.The National Council for Air and Stream Improvement, Inc. (NCASI) serves forest landowners, managers, and the forest products sector as a center of excellence for providing technical information and rigorous scientific research needed to achieve the sector's environmental goals and principles, including forest conservation. NCASI (http://www.ncasi.org) has a long history of research investigating forest ecology and management. NCASI has collaborated with state and federal agencies, universities, and others on studies investigating these and related topics (e.g., Euler and Wedeles 2005). We offer the following information about difficulties in establishing overarching definitions of old-growth and mature forests, the need to manage these forests, and considerations in using remote-sensing technology to inventory old-growth and mature forests.SummaryConsiderable effort has been expended by the U.S. Forest Service, and others, to develop definitions for old-growth forests. The primary conclusion from this work is that there is not a single definition of old-growth that will be universally applicable across the U.S. Further, "mature forest" is not a scientifically recognized forest category. Forests that may be considered mature often require forest management to maintain ecosystem services and forest health. It is important to recognize the limitations and challenges of using remote sensing and the Forest Inventory and Analysis database (FIAdb) to identify and categorize old-growth and mature forests. We encourage the U.S. Forest Service to clearly articulate the difficulties of a single definition for old-growth forests and to recognize the need to manage mature forests for multiple ecosystem services. Finally, the U.S. Forest Service needs to articulate assumptions and uncertainties associated with a U.S.-wide inventory of old-growth and mature forests.Old-Growth DefinitionsThe U.S. Forest Service and other agencies have already expended considerable effort in attempts to define old-growth. For background on this effort, see White and Lloyd (1994). The primary conclusion of this collective effort it that there is not a single definition of old-growth forest that will be useful for conservation and management and that a single set of indicators or criteria will not work universally. It seems likely that a universal definition would be too general to be useful or even operational. For example, old-growth based on tree size would not apply to some forest types, such as subalpine forests, where trees never get very large. Similarly, a definition based solely on age may not capture the structural definition of old-growth. In recognition of this, the U.S. Forest Service developed an entire series of General Technical Reports to define old-growth by specific forest types (Table 1), with multiple types defined for the eastern U.S. alone. From this body of work, it is clear that old-growth forests need to be defined within a forest type, based on scientific expertise and experience, rather than a single definition applied across broad geographic or ecological extents.In fact, local definitions have been used in U.S. National Forests and other jurisdictions of federal land to map old-growth and define management of these forests (White and Lloyd 1994). For discussion of the complexities of defining old-growth, we additionally suggest Braumandl and Holt (2000), McElhinny et al. (2005), Mosseler et al. (2003), Trofymow et al. (2003), and Wirth et al. (2009). For federal land units that have already mapped old-growth, it is not clear how a repeat effort adds value.The request for information included how a definition can incorporate the effects of disturbance on forests. Forests follow successional pathways after major disturbances such as fire. These pathways are relatively well-known but the forest after a major disturbance may no longer be old-growth or even mature forest. Minor disturbances, such as the blowdown of a few trees, are already incorporated into the existing frameworks (Table 1).Mature Forest Definitions"Mature forest" is not a recognized category or forest classification. An attempt was

made by Oliver and Larson (1996) to define "mature" as the stage between closed canopy and gap initiation (old-growth) conditions. The mature stage was argued to be the stage of re-initiation of the understory and sub-dominant trees. However, this model only seems to apply to stands initiated by stand-replacing events, such as wildfire or insect outbreaks, and following a particular development trajectory. It would not apply to broadleaf forests or ponderosa pine (Pinus ponderosa) forests, for example. Their model is not widely used and other research and publications defining "mature" are lacking.If "mature forests" includes closed canopy stands with larger trees, then many relatively young forest stands, including those being commercially managed on relatively short rotations, may be classified as "mature." Classifying such forests as "mature" and removing them from potential harvesting will constrain wood supply.In many cases, management is needed to restore or maintain ecological function of mature forests. This includes creating canopy gaps not only for regeneration of some critically important tree species (e.g., oaks (Quercus spp); McShea et al. 2007), but also to create appropriate conditions for some older forest-associated species (e.g., cerulean warblers (Setophaga cerulea), a declining species of concern; Nareff et al. 2019). It is also important to manage forests to protect forest health. On private lands, management maintains an incentive for keeping forests as forests (sustainable use; National Commission on Science for Sustainable Forestry 2005).Identifying Old-Growth and Mature ForestsCurrently, the FIAdb and satellite remote sensing are the only data sources available that may contribute to identifying old-growth and mature forests at the national scale, yet both come with challenges and limitations. Existing old-growth definitions include variations of finer scale forest characteristics such as crown closure; quantity of down dead wood and snags; and tree species, age, and density (see references in Table 1). Therefore, these data sources must be used to estimate these forest characteristics at fine spatial scales and with a high degree of accuracy, which may not be possible.When a definition of old-growth or "mature forest" is based upon measurable criteria typically recorded in forest inventories, then inventory information can be used to quantify the magnitude and spatial extent of old-growth forest coverage nationwide using national forest inventory data. For example, Davis et al. (2015) described a quantitative index (the Old-growth Structure Index, or OGSI) that can be used to characterize the extent to which a forest area has the characteristics associated with old-growth forest. This index is based on threshold values of quantities such as density of large live trees, diversity of live tree size classes, density of snags (dead trees), and percent cover by down dead wood. Using this system with tree measurements from the FIAdb, it is possible to compute a score for each plot representing how well the plot exemplifies characteristics of old-growth. It should be noted that this index builds upon prior work published in the late 1980s, so it is decades in the making. However promising this approach may be, it currently is limited to forests in the Pacific Northwest. It is also important to recognize that while the FIAdb can give an indication of total acres in various forest categories over large extents, it is not possible to use it to produce detailed maps due to the wide dispersal of field plots (roughly one per 6,000 acres).Remote sensing has allowed for investigations of land systems over large spatial and temporal scales and has also been proposed as a method for identifying mature and old-growth forests. In the late 1980s and early 1990s, researchers attempted to identify old-growth forests in the western United States using remote sensing [projects reviewed by Norheim (1997) and Norheim (1998)]. However, results from these two studies drastically differed for similar study areas despite using a comparable definition for old-growth forests. While satellite technologies have advanced over the last few decades, we are still faced with similar challenges and limitations. More recent studies that have sought to estimate forest type, forest stand attributes, or directly identify old-growth stands have seen varying success with accuracies typically less than 80%, while mixed species stands have seen accuracies less than 50% (Liu et al. 2018; Spracklen and Spracklen 2019; Illarionova et al. 2021). Lu (2005) found that estimating forest parameters in "mature forests" was limited using remotely sensed data, likely due satellite signal saturation from forest stand complexities [also reviewed by Roberts et al. (2007)]. However, classification of "mature forests" relative to earlier successional stages and agricultural land obtained higher accuracy (>80%) (Lu et al. 2004). These two studies did not attempt to define or differentiate "mature forests" from old-growth forests and would likely have seen even lower accuracies had this component been incorporated, such as seen in Cohen et al. (1995) and Fiorella and Ripple (1995). Thus, it is unclear if a "mature" category can be well-separated from old-growth using remote sensing data. Remote sensing data are often at coarser spatial resolutions than the processes being predicted and have varying degrees of uncertainty. In addition, it is sometimes difficult to separate the true signal from "noise" introduced via clouds and aerosols in the atmosphere (optical satellites; passive sensors) or interaction of out-ofphase waves (active synthetic aperture radar; SAR; active sensors).While the exact methodology used for identifying old-growth forests will differ based on its definition, it will likely be best achieved using a combination of optical and SAR remotely-sensed data and ground-based field measurements. This is because no single data source provides comprehensive forest information (e.g., optical satellites are unable to thoroughly assess the vertical variability within forest stands with dense canopy cover). Inclusion of auxiliary information (e.g., elevation and textural features; see Spracklen and Spracklen (2019)) may improve model performance when working with remotely sensed data. Model calibration and validation using ground-based field assessments (e.g., FIAdb) will be essential to this process given that relatively young and old-growth forests can have similar characteristics (e.g., closed canopies or down dead wood). Uncertainty, noise, and the spatial scales of each data source should be addressed throughout this process. It does not seem likely that appropriate ground-truthing can be accomplished in the timeframe for completing the inventory process (April 2023). Without ground-truthing, it is impossible to know if a classification method is working as intended and to quantify uncertainty. We strongly encourage the Service to clearly state the assumptions and limitations of a national inventory of old-growth and mature forests, especially if ground-truthing is not conducted.

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