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Thank you for the opportunity to comment on the Request for Information on Federal Old-growth and Mature Forests. The mission of the Ecological Restoration Institute (ERI) at Northern Arizona University is to serve diverse audiences with objective science and implementation strategies that support ecological restoration and climate adaptation on Western forest landscapes. The ERI supports landscape-scale restoration strategies that incorporate long-term fire risk reduction to build climate resiliency in high-priority landscapes.

The following comments were prepared by ERI staff to provide the best available science from our expertise on frequent-fire forests on this topic.

Below please find our comments following each heading; cited literature can be found listed below with hyperlinks as available:

- *What criteria are needed for a universal definition framework that motivates mature and old-growth forest conservation and can be used for planning and adaptive management?*
    - To date, there is no single, universal definition framework that can be used to describe mature and old-growth forests across our ecologically diverse federal lands.
    - Published studies since the 1990's have identified the difficulty of defining old-growth, and instead recommend a variety of system-specific characteristics incorporating appropriate spatial and temporal scales (Spies et al. 2004, 2006, Kaufmann et al. 2007, Fiedler et al. 2007, Pesklevits et al. 2011, Davis et al. 2015).
    - We suggest the development of a hierarchical framework that tiers from general, natural disturbance regime characteristics (e.g., frequent, low-severity to infrequent, stand-replacing disturbances) to finer scale structures and compositions to identify ecosystem-specific old-growth and mature forest states or species-specific tree demographic attributes that designate maturity. More research is needed to describe late-stage conditions for many forest ecosystems (see also below).
    - The use of an old-growth definition would be helpful in prioritizing restoration and fuel reduction projects, but as one of multiple objectives, that need to be considered in moving forward with comprehensive and climate-informed wildfire risk reduction strategies. Examples include, but are not limited to:
        - Climate change vulnerability and shifting ecosystems
        - Infrastructure and community protection
        - Landscape-level fire restoration, and mitigation
        - Sustainability of ecosystem services

- *What are the overarching old-growth and mature forest characteristics that belong in a definition framework?*
    - Any definition of "old", "old-growth" or "mature" would need to be designated for individuals and stands/communities/assemblages separately; definitions should account for species- and assemblage-specific evolution, life span and life histories; definitions should clearly define the temporal and spatial scales over which it applies; and where possible be unique to bio-geoclimatic regions and include anthropogenic values, such as scarcity, cultural and spiritual value, and visual and emotional impression.
    - Here are some relevant criteria specific to all ecosystems:

        - Ecosystem structure
        - Ecosystem composition
        - Ecosystem function and process
        - Scale, including spatial and temporal designations
        - Values, representing those of Indigenous and diverse social and economic perspectives.
    - For different forest types Relevant criteria for specifically for frequent-fire forests should include:
        - Old-growth and old-tree structure that are spatially heterogenous, often in mixed aged groups. These forests do not follow a replacement-successional stage model (Spies et al. 2006, Reynolds et al 2013)
        - The characteristics of old growth, and the needed elements to conserve old-growth and old-trees, in frequent-fire forests includes the following structural attributes (Reynolds et al. 2013):
            - Composition dominated by fire-adapted species including ponderosa pine, with diverse understory species dependent on geographic regions, soil type, and climate patters.
            - Spatial components of individual trees, groups of trees, and open grass-forb-shrub openings.
            - Habitat structures including snags, logs, and wood debris
        - Forest structure found in today's frequent-fire forests, including remaining stands of old trees, are highly departed from their evolutionary forest structure, specifically with regard to tree density of younger trees and fuel loading (Feidler et al. 2007, Pritchard et al. 2021); the remaining old tree stands found in these conditions are at highest risk of loss to uncharacteristically severe fire, and not logging (Davis et al. 2015).
        - Old tree and old-growth mapping may allow prioritization of fire risk reduction treatments to protect the remaining old trees in frequent-fire forests.

- *How can a definition reflect changes based on disturbance and variation in forest type/composition, climate, site productivity and geographic region?*
    - As we state above, a universal old-growth definition cannot reflect the diversity of ecosystems and forest types found across North American and on US public lands (Spies and Franklin 1996).
    - Instead, a framework based on ecosystem structure, composition, and function, across spatial and temporal scales, would allow for the variability found across our biodiverse public lands. (Spies and Franklin 1996, Kaufmann et al. 2007, Fiedler et al. 2007, Spies et al. 2004, 2006, Davis et al. 2015)
        - This framework is challenging all ecosystems because there is currently no adequate dataset that provides sufficient resolution and quality to measure this. Additional data sources include the LANDFIRE initiative (www.landfire.gov) that incorporates multiple sources of information to describe forest conditions wall-to-wall, as well as the FIA program.
    - We encourage acknowledgement of the specific natural processes, compositions, and structural elements necessary for old-growth forest development given the specifics of the forest ecosystem in question. Further, we encourage acknowledgment of the importance of restoration and conservation activities that may be necessary in these earlier successional

stages to facilitate the eventual development and replacement of old or mature trees and old-growth conditions on the landscape.
  - A framework should also acknowledge the past millennia of human activity and management by indigenous peoples, and incorporate cultural management values into a decision-framework (Murphy et al. 2007).
  - We recommend utilizing local plot-based data (e.g., FIA) as well as modern remote-sensing technologies (e.g., passive satellite sensors as well as active sensors such as LIDAR) to develop landscape models for tracking old-growth conditions (e.g., Barros and Elkin 2021).

- *How can a definition be durable but also accommodate and reflect changes in climate and forest composition?*
  - A definition framework should not supersede the set of scientifically and collaboratively-developed desired conditions developed over the last 20 years that have facilitated the restoration of ecosystem function.
  - A definition should be based on ecological function and process; prescriptive characteristics of old trees could limit adaptation needed due to climate and forest composition.
  - We encourage acknowledgment of the role of ecological restoration and science-based management in helping to facilitate old-growth development on landscapes and forest sites where modern land-uses have led to ecosystem degradation and departure from natural successional trajectories.

- *What, if any, forest characteristics should a definition exclude?*
  - Ecological characteristics based on single species are not advised. For example, tree diameter, size, and/or age criteria are ecosystem specific (Kaufmann et al. 1992). Thus, basing management decision on such limits can have unintended consequences that include lack of adaptability for species composition, or soil productivity.
  - Definition should not include criteria for a general lack of disturbance or focus on conditions being "extraordinary" or "rare" on the landscape to define the condition. These terms may create a narrow definition and could devalue their current and future conservation value.
  - Limitations on forest management practices, including fire suppression, or mechanical thinning of small trees, should be avoided to better facilitate use across multiple ecosystems.

Citations:
The following set of papers, plus an additional 6 articles on old growth, can be found at https://ecologyandsociety.org/feature/33/, which was a special issue of Ecology and Society publishing the results of a 6 months writing workshop on old growth definitions, management, and conservation practices:

Egan, D. 2007. Editorial and Summary of Special Session: Conserving and restoring old growth in frequent-fire forests: cycles of disruption and recovery. Ecology and Society 12(2):23. https://ecologyandsociety.org/vol12/iss2/art23/

Fiedler, C.E., P. Friederici, M. Petruncio, C. Denton, and W.D. Hacker. 2007. Managing for old growth in frequent-fire landscapes. Ecology and Society 12(2):20. https://ecologyandsociety.org/vol12/iss2/art20/

Kaufmann, M.R., D. Binkley, P.Z. Fule, M. Johnson, S.L. Stephens, and T.W. Swetnam. 2007. Defining old growth for fire-adapted forests of the western United States. Ecology and Society 12(2):15.

Kaufmann, M.R., W.H. Moir, and W.W. Covington. 1992. Old-growth forests: what do we know about their ecology and management in the Southwest and Rocky Mountain regions? Pp. 1-11 in Kaufmann, M.R., W.H. Moir, and R.L. Bassett (tech cords.) Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop. USDA Forest Service General Technical Report RM-213. 201 p.

Murphy, A., J. Abrams, T. Daniel, and V. Yazzie. 2007. Living among frequent-fire forests: human history and cultural perspectives. Ecology and Society 12(2):17.

Additional citations include:

Barros, L.A. and C. Elkin. 2021 An index for tracking old-growth value in disturbance-prone forest landscapes. Ecological indicators 121:107175. DOI: 10.1016/j.ecolind.2020.107175

Davis, Raymond J.; Ohmann, Janet L.; Kennedy, Robert E.; Cohen, Warren B.; Gregory, Matthew J.; Yang, Zhiqiang; Roberts, Heather M.; Gray, Andrew N.; Spies, Thomas A. 2015. Northwest Forest Plan–the first 20 years (1994-2013): status and trends of late-successional and old-growth forests. Gen. Tech. Rep. PNW-GTR-911. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 112 p. Davis et al. 2015. https://www.fs.usda.gov/pnw/pubs/pnw_gtr911.pdf

Pawlikowski, N.C.; Coppoletta, M.; Knapp, E.E.; Taylor, A.H. 2019. Spatial dynamics of tree group and gap structure in an old-growth ponderosa pine-California black oak forest burned by repeated wildfires. Forest Ecology and Management 434:289-302.

Pesklevits, A.; Duinker, P.N.; Bush, P.G. Old-growth Forests: Anatomy of a Wicked Problem. Forests 2011, 2, 343-356. https://doi.org/10.3390/f2010343

Prichard, S. J., et al. 2021. Adapting western North American forests to climate change and wildfires: 10 common questions. Ecological Applications 00(00):e02433. 10.1002/eap.2433

Reynolds, Richard T.; Sánchez Meador, Andrew J.; Youtz, James A.; Nicolet, Tessa; Matonis, Megan S.; Jackson, Patrick L.; DeLorenzo, Donald G.; Graves, Andrew D. 2013. Restoring composition and structure in Southwestern frequent-fire forests: A science-based framework for improving ecosystem resiliency. Gen. Tech. Rep. RMRSGTR-310. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 76 p

Spies, T.A. 2004. Ecological concepts and diversity of old-growth forests. Journal of Forestry April/May 2004. https://academic.oup.com/jof/article/102/3/14/4613151

Spies, T.A. and J.F. Franklin. 1996. The diversity and maintenance of old-growth forests. In Szaro, R.C. and D.W. Johnston, eds. Biodiversity in Managed Landscapes: Theory and Practice. Oxford University Press. New York. 778 pages. https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub1414.pdf

Spies, T.A., M.A. Hemstrom, A. Youngblood, and S. Hummel. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology 20(2)::351-362. DOI: 10.1111/j.1523-1739.2006.00389.x