Does roadless rule? Social-ecological consequences of the Roadless Area Conservation Rule

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Abstract

The Roadless Rule, established 25 years ago to maintain 58.5 million federal forest acres in roadless condition, is one of the U.S.'s most expansive and debated natural resource experiments. We synthesize research on the effects of the Roadless Rule on biodiversity, wildfire, forest and watershed health, and economics to guide current and future decision making. Research shows the Roadless Rule provides substantial biodiversity protections. Wildfire outcomes of the Roadless Rule are mixed. Compared to roaded federal forests, Roadless Areas have fewer human-caused ignitions, similar wildfire severity, and tend towards larger wildfires. Although management occurs in Roadless Areas, it remains unclear if wildfire interventions and outcomes sufficiently match management goals. The Roadless Rule protects large watershed areas and river lengths and provides drinking water to millions of Americans. Even so, the Rule's effects on water quality or supply are largely unmeasured. The Roadless Rule often benefits rural economies – largely through recreation and amenity values – with possible tradeoffs. Retaining the Rule would maintain conservation and existing economic benefits. Rescinding the Rule would impair these benefits. Increasing protections for Roadless Areas could constrain necessary management without clear benefits. Adjustments to the Roadless Rule may increase management flexibility and would benefit from effectiveness research.

Introduction

The Roadless Area Conservation Rule ("Roadless Rule") was established by the U.S. Forest Service (USFS) in 2001 to protect high-integrity landscapes for diverse values including biodiversity, watershed health and drinking water, and dispersed recreation (66 FR 3244). The Rule restricts road construction and timber harvests across approximately 58.5 million acres (23 million ha; roughly the size of the United Kingdom) of inventoried roadless areas (IRAs), covering roughly one-third of all National Forest land. Although IRAs occur in nearly 40 states, they occur predominantly in western states (Figure 1). IRAs can represent relatively large proportions of some states, and some states contribute substantially to the nation's IRA system (Figure 2).

Along with establishing the National Wilderness Preservation System, the Wilderness Act of 1964 directed the USFS to inventory roadless areas that could potentially be later included in the Wilderness system. Congress eventually released undesignated roadless areas to the USFS to integrate into its multiple-use mandates but, after continued debate about their value and fate, these inventoried roadless areas (IRAs) became the foundation of the Roadless Rule in 2001 (Holmes 2022). Notably, although the Rule has been in effect for 25 years, many IRAs were largely *de facto* managed in the same manner pre- and post-Rule. For a quarter century, the Roadless Rule has emerged as one of the most expansive – and controversial – land management policy experiments in United States history (Holmes 2022).

The Roadless Rule is an administrative rule, not legislation. In contrast to legislatively codified land use allocations, such as designated Wilderness Areas, "rules" are administrative decisions by agencies in cases where statutes have room for interpretation. Such rules are typically less durable than Congressional acts and can be more easily modified by subsequent administrations. As such, since it was enacted, the Roadless Rule has received continuous debate about repeal or modification – such as state-level alterations for Idaho and Colorado (73 FR 61456, 77 FR 39576).

Some have also advocated for *increasing* protections for IRAs, similar to Wilderness designations (Holmes 2022). Importantly, although some have suggested that the Roadless Rule constrains wildfire management and other forest health goals (66 FR 3244, 90 FR 42179), IRA designation does not preclude all active management, allowing for prescribed fire, vegetation treatments like thinning out forests of smaller-diameter trees, and emergency road construction. IRAs thus occupy a functional middle position on the management-intensity spectrum between congressionally designated Wilderness, where almost all human interventions are excluded, and roaded National Forest lands, which can be subject to more intensive interventions and extractive uses including logging, mining, and road construction (Figure 3).

In June 2025, the U.S. Department of Agriculture (which houses the USFS) announced its intent to rescind the Rule, citing constraints on wildfire suppression and forest health management (90 FR 42179). Yet despite a quarter century of implementation across an enormous and spatially varied land area, no peer-reviewed systematic review of the Roadless Rule's ecological consequences has been published. Now, with 25 years since the Rule’s implementation and to guide current and future decision making, we synthesize the best available science on effects of the Roadless Rule on biodiversity, wildfire, forests pests and invasive species, watershed condition, and economics. We focus on these outcomes as they undergird both the motivation for establishing the Roadless Rule and for removing it (66 FR 3244, 90 FR 42179). Specifically, our review asks what the effect of the Roadless Rule has been on biodiversity, wildfire, forest pests, watershed conditions, and economics relative to other federal administrative forest designations. The comparisons allow us to synthesize relevant science on forests with greater or lesser protections than the Roadless Rule confers.

Methods

The literature on “road effects” is vast (Forman and Alexander 1998, DellaSala and Frost 2001, Trombulak and Frisell 2000, Gucinski et al. 2001, Ibisch et al. 2016, Kastridis 2020). Here we constrain our synthesis to literature that explicitly measures effects of IRAs relative to other USFS and/or National Park (NPS) administrative designations, rather than general road effects. This approach treats IRAs and other administrative units as different pseudo-experimental treatments, allowing us to understand the cumulative effects of roadless area designations.

We used Harzing’s ‘Publish or Perish’ software to query Google Scholar for the phrase “roadless rule” to comprehensively search the literature for publications relevant to the Rule. We also searched “roadless rule water”, “roadless rule fire”, “roadless rule pest”, “roadless rule wildlife”, “roadless rule biodiversity”, and “roadless rule habitat” in case these provided additional references. For each query, we restricted our search to the references within the top 100 most relevant Google Scholar scores, resulting in 312 unique publications after removing duplicate entries across queries (Figure 4). We evaluated publications that were empirical studies of the effects of the federal Roadless Rule on wildfire, biodiversity, watershed condition, economics, and forest pests (and inclusive of pathogens, invasive species, and disease). After screening titles and abstracts, we removed 126 references that clearly did not match our criteria (e.g., were general perspectives, non-research articles, legal analyses). Of the remaining entries, we included articles that contained novel empirical data relevant to our review's criteria (Figure 4). To our knowledge, no prior synthesis like ours exists to build on.

Research comparing IRAs to more and less protected lands typically relies on U.S. Geological Survey (USGS) GAP Analysis Project (GAP) designation codes, which assign lands designations ranging from 1 to 4 based on the degree and durability of protections, where GAP 4 has no known protections (Dietz et al. 2023). IRAs are largely categorized as GAP 3 lands but may be reasonably considered as similar to GAP 2 or intermediate to GAP 2 and GAP 3 lands given their increased but potentially unstable protections (Dietz et al. 2023). We focus on research that compares IRAs to more protected land designations (e.g., Wilderness, other GAP 1 lands) and/or less protected lands (less-protected USFS land with more intensive land use, other GAP 3 lands). The logic behind this approach is that the Wilderness Act, Roadless Rule, and the USFS's broader multi-use mandate functionally create a gradient of protections and restrictions on human interventions into natural processes (Figure 3). Because USFS lands with different protection statuses are often spatially proximate, there is potential to test whether administrative designations on the land translate to environmental differences (Figure 1). Our approach allowed us to synthesize the consequences of the Roadless Rule *specifically* rather than extrapolating research findings from other contexts. IRAs were not necessarily established to be representative of the breadth of forest conditions (ecoregion, latitude, etc.) available across USFS lands and so we note when our understanding of Roadless Rule effects is hindered by potential covariation with biophysical conditions.

Of the 312 unique publications identified by our search, only 17 (across peer-reviewed and gray literature) were relevant to our review's criteria on Roadless Rule impacts relative to other forest designations. The remaining publications were dominated by legal analyses and perspectives. Roughly two dozen publications were about general roadlessness in other contexts (e.g., other countries, non-IRA roadless areas). One additional study was published after we initiated our literature search (Aplet et al. 2026) and another from prior to the Rule's finalization (DeVelice and Martin 2001) was identified in the references of the literature recovered from our review; both were included in our review for a total of 19 studies. Two other studies were also published in this time frame (Johnston et al. 2025, Olden et al. 2026) but do not make comparisons to more or less protected forest designations; we use these studies in our review for context but note the limited interpretability. We further contextualize the synthesized body of research with other relevant studies and make clear when these studies provide comparisons to other forest designations. The research synthesized here can provide decision makers now and in the future with direct, synthesized scientific evidence about the consequences of one of the largest natural resource experiments in the country and world, and the implications of past, current, and future decision making.

Results

Biodiversity

Increasing protections for biodiversity was a motivating factor for establishing the Roadless Rule (66 FR 3244). Since the Rule's implementation, a steady stream of research has found that IRAs increase the representation and diversity of ecosystem types and species diversity within the protected area network, while also bolstering connectivity, increasing habitat patch size, and enhancing the functional protected area for species. For example, Crist et al. (2005) report that the designation of IRAs in the Northern Rockies nearly double the amount of area protected compared to only considering Wilderness, National Parks, and Wildlife Refuges. IRAs also nearly double the mean patch size of protected areas and decrease the distance between protected habitat patches by about 25% (Crist et al. 2005). IRAs contribute to increased representation of protected species and habitats in part because IRAs tend to occur at lower- and mid-elevational ranges, where more species and habitat diversity are located, compared to the higher elevations often represented in Wilderness areas (DeVelice and Martin 2001, Strittholt and DellaSala 2001, Loucks et al. 2003, McClure and Dickson 2019, Talty et al. 2020, Law et al. 2021, DellaSala et al 2021). Importantly, the median number of at-risk species in a forested area is similar between GAP 1 and 2 USFS lands, IRAs, and other USFS lands, meaning that Roadless Areas are not inherently more biodiverse than other USFS lands, but that they offer different species protections than would otherwise exist (Dietz et al. 2021).

Further, recent analysis shows that 55% of IRAs are in the top quintile of least modified lands in the conterminous U.S. (Talty et al. 2020) and IRAs contain over a third of all old growth and over a quarter of all mature forests on USFS lands (DellaSala et al. 2024, Lamping et al. 2026). An analysis of the Southern Rockies and Santa Fe Subregions finds that IRAs functionally double the habitat protections for Mexican spotted owl (*Strix occidentalis lucida*) and northern goshawk (*Accipiter gentilis*) and provide an approximately 50% increase in Canada lynx (*Lynx canadensis*) habitat compared to other relatively well-protected GAP 1 and GAP 2 lands (DellaSala et al. 2024). In general, IRAs provide substantial protections for >300 listed species (Dietz et al. 2021). Indeed, at least a dozen listed species have over 10% of their habitats contained in a single IRA and some species of listed amphibians and mammals have 40-50% of their entire habitat in IRAs (Dietz et al. 2021). Nationally, species richness is similar between GAP 1 and 2 USFS lands, IRAs, and other USFS lands, but that pattern differs by region (Dietz et al. 2021). For instance, Utah's IRAs generally encompass a disproportionate number of at-risk species per hectare compared to other USFS lands, with most IRAs supporting over two dozen at-risk species (McClure and Dickson 2019).

Aquatic species in IRAs are less studied than terrestrial species. A recent analysis using IUCN Red List data found that ~20% of watersheds that are influenced by IRAs (either 5% of the watershed is in an IRA or watersheds within 160 river km downstream of an IRA boundary) rank within the top quarter for aquatic biodiversity richness within respective U.S. states, although this study did not provide a direct comparison for aquatic biodiversity in more or less protected forested watersheds (Olden et al. 2026). A study in Utah reports that Utah's IRAs support a diversity of at-risk amphibian, reptile, mollusk, and fish species (McClure and Dickson 2019). And a report details over 1,200 occurrence records of target fish species like native west slope cutthroat (*Oncorhynchus clarkii lewisi*), pure populations of rainbow trout (*Oncorhynchus* *mykiss*), bull trout (*Salvelinus confluentus*), Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), and other fishes in Montana IRAs (Frissell and Carnefix 2007). This Montana study suggests that the protections provided by IRAs may be particularly helpful for fishes like trout because, unlike IRAs, many Wilderness Areas and National Parks have headwater lake basins that were targeted for introducing nonnative trout that can hybridize or displace native populations and species. Finally, the Idaho Giant Salamander (*Dicamptodon aterrimus*) - a freshwater-dependent, headwater stream species – is highly reliant on IRAs, with more than 25% of its suitable habitat occurring in IRAs (Dietz et al. 2021).

Although most biodiversity studies focused on ecosystem and species diversity, some field research assessed individual species in IRAs. Research in Colorado shows that Canada lynx reintroductions and recovery rely on IRAs. Specifically, IRAs comprise more than 25% of lynx core habitat, similar to the amount protected in National Parks and Wilderness (Squires et al. 2025). And a study in Alaska's Tongass National Forest presents mixed results on the effects of roads and prior timber harvest on wolf movement and habitat use, making it unclear whether changes in IRA protections and habitat management would influence wolves in the area (Gregovich et al. 2025). Notably, because Alaska’s USFS lands (Tongass and Chugach) are heavily comprised of IRAs and have changed designations in recent years, comparisons to non-IRA USFS lands in Alaska are likely limited. Even so, the Alaska’s USFS are among the most expansive and intact in the country, harbor multiple forest designations, and have a variable history of intensive management which provides opportunities to assess effects of different land uses (Law et al. 2023).

Some researchers argue that conservation goals would be improved and more durable if IRAs were given additional protection (DellaSala et al. 2024). Alternatively, others argue that IRAs' less "protected" status allow for more proactive habitat and species management. Indeed, Johnston et al. (2021) suggest that conservation objectives in IRAs may benefit from the more intensive management allowed. For example, IRA designations should allow the USFS to mediate wildfire activity by cutting trees and using controlled burns, which can also help maintain suitable habitat (e.g., for Canada lynx, Squires et al. 2025). Even so, protections in Wilderness areas and IRAs can constrain restoration management. For instance, white bark pine (*Pinus albicaulis*) is a keystone tree that benefits a diversity of species, but which has been declining due to disease, pests, warming temperatures and fire suppression. Despite substantial white bark pine occurring in Wilderness and IRAs, protections in those forest lands have constrained most management for whitebark pine to other multiple-use USFS lands with lower protections (Keane 2000, Hansen et al. 2016, Ireland et al. 2018). Importantly, habitat treatments to promote biodiversity and declining species can be essential even in mature and old growth forests (Jones et al. 2025) which are highly represented in IRAs (DellaSala et al. 2024, Lamping et al. 2026).

The weight of scientific evidence demonstrates that the Roadless Rule provides unique protections for a greater diversity and complement of habitat and species than currently found in existing strictly protected areas like Wilderness. Further, many species receive much or most of their protections because of the Roadless Rule. We note that much of the research here assumes that protection under the Roadless Rule is sufficient for biodiversity conservation. Interestingly, a recent analysis found that watersheds influenced by IRAs provide pronounced opportunities both for aquatic biodiversity or for fishing and hunting opportunities, but that biodiversity and fishing/hunting opportunities were poorly correlated in the same watershed (Olden et al. 2026). Additional research analyzing what aspects of IRAs contribute to biodiversity versus hunting and fishing opportunities could prove useful to ongoing management. The synthesized research does not indicate that increases in management restrictions would further benefit biodiversity; rather, conservation goals may require active habitat or population management that could be restricted in more protected designations like Wilderness Areas.

Wildfire

Wildfire management has emerged as one of the key issues underlying debates around maintaining versus diminishing the Roadless Rule (90 FR 42179). The Roadless Rule does not prohibit fire suppression operations in IRAs. When the Rule was established, it documented that the USFS had historically used various interventions to achieve high suppression rates for most ignitions, containing fires at relatively small sizes in IRAs (66 FR 3244). Further, the Roadless Rule explicitly allows for forest health treatments (e.g., thinning of small diameter trees, implementing prescribed fire) for reducing the risk of uncharacteristic wildfire (66 FR 3244). The USFS applies a risk-based wildfire response framework to all fires on National Forest System lands regardless of administrative designation, with the full range of strategic and tactical options available for every wildfire (Fire Executive Council 2009, United States Forest Service 2020). Fire research around IRAs was relatively limited in the first decade since the Roadless Rule was implemented (but see Eastman et al. 2002) but has increased in recent years and focused on ignitions, burned area, fire size, and severity.

Fire Effects

Research shows that, on both roaded and Roadless Area USFS lands, human-caused fires are more common near roads, in areas that have higher road densities, or areas which are near the wildland urban interface (WUI) (Aplet et al. 2026, Narayanaraj and Wimberly 2012). Indeed, wildfire risk is growing in the American WUI generally (Radeloff et al. 2023). A recent analysis of wildfire data from the early 1990's to 2024 compares fire ignitions (human and natural) in Wilderness Areas, IRAs, and other USFS lands within and beyond 50m of a road (Aplet et al. 2026). Ignition rates are similarly low in Wilderness Areas and IRAs (1.8 and 2.0 fires/1000ha, respectively), and 1.5-4x higher in other USFS lands, with the highest densities (~8 fires/1000ha) within 50m of roads (14). For all USFS lands, ignition rates are concentrated near roads and decrease markedly beyond 2km from roads (Aplet et al. 2026).

Although ignitions are more common near roads, burned area (cumulative area affected by one or more fire events) is not necessarily greater near roads. One analysis of burned area across USFS lands from 1985 to 2016 concludes, without formal statistical analysis, that burned forest area in IRAs is proportionally similar to all other USFS lands (19% vs 18% burned, respectively) (Healey 2020). In contrast, at a regional scale, research from Washington's Okanogan-Wenatchee National Forest finds that lightning fires comprised >90% of the acreage burned, that there is twice as much lightning fire acreage burned in IRAs compared to Wilderness, and there is four times as much acreage burned in IRAs compared to roaded forest lands (Narayanaraj and Wimberly 2012). Although this study excludes unburnable areas (e.g., rock), it did not describe the relative percentage of IRA and Wilderness area burned, so it remains unclear if the greater number of burned acres in IRAs relative to Wilderness is disproportionate.

In a more direct analysis of fires by forest designation, mean fire size (area within an individual fire's perimeter, potentially including some unburned patches) is 135 ha in IRAs, compared to 239 ha (77% larger) in Wilderness, and 62 ha (54% smaller) in other USFS lands (Aplet et al. 2026). Conversely, median fire size is identical and small (0.04 ha) across designations. This is because mean fire size is driven by a relatively few but very large, fires; these are more common in Roadless Areas (Aplet et al. 2026). The majority of the 20 largest fires on USFS lands in recent decades began in IRAs, even though IRAs account for about 1/3 of USFS land (Johnston et al. 2021). Overall, there appears to be a tradeoff among USFS designations between ignition frequency and fire size (Figure 5).

Research on fire severity is relatively limited. Some earlier work suggests IRAs have fire severities that are greater than Wilderness areas but lower than roaded areas (Bradley et al. 2016). At the same time, more recent analyses find that fire severity tends to be similar between Wilderness, IRAs, and roaded USFS lands (Johnston et al. 2021). While not directly evaluating IRAs, Chamberlain et al. (2024) compared the 2021 Schneider Springs (Washington State) and Bootleg (Oregon) wildfires and found that distance to roads was a key predictor of wildfire severity across land management allocations in the Schneider Springs but not the Bootleg fire. Areas closer to roads may provide greater wildfire management options, leading to lower fire severity in some cases (Chamberlain et al. 2024). Roads are only one type of potential control location and so their potential utility for fire control are best considered in the context of broader land and fire management goals (United States Forest Service 2023).

Interpretation

Compared to more heavily managed and roaded USFS lands, evidence to date suggests that IRAs have fewer human-caused fire ignitions, similar or variable fire severity, and a higher probability of large wildfire size and burn area compared to roaded USFS lands. This research suggests a potential tradeoff between ignition rate and fire sizes, with IRAs exhibiting relatively low ignition rates but larger fire sizes (Figure 5) (Aplet et al. 2026). Importantly, multiple studies suggest that fire outcomes (e.g., escape, extent, severity) are more strongly shaped by biophysical variables (vegetation type, fire and temperature regimes, elevation, precipitation, etc.) and fire weather than by administrative management regimes (e.g., IRA vs other USFS lands; Aplet et al. 2026, Johnston et al. 2021, Narayanaraj and Wimberly 2012, Bradley et al. 2016). Without accounting for vegetation type, characteristic fire regime, productivity, topography, and climate, it is not possible to know if potential differences in fire characteristics are caused by management regime.

If IRAs do host larger fires, this does not necessarily mean that IRAs are inadequately managed for fire. Recent analyses indicate that contemporary fire extent is not unprecedented relative to historical fire regimes (Parks et al. 2025), although fire severity and patch configuration may be novel or historically atypical (Cova et al. 2023). The low-to-moderate severity portions of large fires can move fire-adapted forests toward more resilient conditions (Cova et al. 2023, Donato et al. 2023). Wildfires that burn with low-to-moderate severity can effectively moderate the severity of subsequent wildfires (Tortorelli et al. 2024).

An analysis of USFS records finds that IRAs represent nearly 10% of total treated forest land, indicating that IRA designations do not restrict forest prescriptions, nor rely solely on passive treatments (38). Although the study incorporates diverse treatments, its analysis does not discern mechanical treatments from prescribed fire, beneficial wildfire, and other treatments across USFS designations. Even so, an analysis of fires in 11 western states finds that fires escaped initial containment efforts ~3X more frequently in IRAs compared to roaded USFS lands and, when they escaped, grew 30% larger (Johnston et al. 2021). An important interpretation of this research is that roaded areas experience more ignitions and treatment due to easier access, reduced road access in IRAs may limit some suppression and containment at scale, but large remote areas in IRAs give managers flexibility to use burning in line with resource management objectives (Johnston et al. 2021). As such, IRA designations may provide a balance between protections and active management (Figure 3).

Management constraints should be interpreted in context. Fuel management activities in IRAs have been more numerous per square kilometer than elsewhere on USFS lands, though treatments in roaded areas cover larger extents (Healey 2020). However, mechanical treatment capacity across western forests is constrained by multiple overlapping factors beyond roadless designation, including Wilderness, steep terrain, distance to existing roads, riparian buffers, and species habitat protections (Prichard et al. 2021). In the central Sierra Nevada, for example, only 25% of the landscape was available for mechanical treatments after all such constraints were applied (North et al. 2015). In addition, workforce capacity is among the major factors limiting the pace of forest restoration on USFS lands, meaning that even where mechanical treatment and prescribed fire are legally and physically feasible, implementation capacity can be a major limiting factor to getting work done on the ground (Schultz and Moseley 2019). As such, the Roadless Rule represents, at most, one of several factors limiting mechanical treatment access across western forests. Rescinding the Rule would not necessarily allow for more mechanical thinning given the prevalence of these other factors. Further, mechanical treatment without subsequent prescribed fire is less effective in moderating wildfire effects (Chamberlain et al. 2024, Davis et al. 2024), yet current analysis did not distinguish among fuel management activities or combinations of sequenced activities (Healey 2020).

Fire size alone is a poor proxy for ecological outcome, and large fires are not inherently detrimental. Large wildfires can produce a wide range of positive ecological effects in fire-adapted forests, including increasing spatial heterogeneity (Churchill et al. 2022), promoting early-seral habitats and associated specialists (Churchill et al. 2022, Larson et al. 2022, Meigs et al. 2025, Tingley et al. 2016, Jones et al. 2022, Steel et al. 2022), increasing survival of large and old trees under some conditions (Meigs et al. 2025), and even benefiting some aquatic species like salmon (Flitcroft et al. 2016). Many fire-adapted forests in the western U.S. are experiencing substantial fire deficits relative to historical conditions (Donato et al. 2023, Haugo et al. 2019). Fires burning in IRAs may be moving landscapes towards, rather than away from, historical fire regime conditions. However, post-fire outcomes are context-dependent, varying across forest type, climate, prior disturbance and treatment, topography, and fire weather, among other variables (Churchill et al. 2022, Larson et al. 2022). The impact of these variables on fire outcomes within IRAs specifically remain understudied. Understanding whether, when, and where large fires in IRAs generate desirable and undesirable ecological outcomes, rather than relying on fire size or extent alone, is an important area for future research.

The expansion of WUI is generally increasing both wildfire risk and exposure U.S.-wide (Radeloff et al. 2023). Indeed, WUI growth near USFS lands is a dominant reason cited for repealing the Roadless Rule (90 FR 42179). Even so, relatively limited research has assessed the effects of IRA proximity and management on wildfire patterns near or within WUI and management (but see Narayanaraj and Wimberly 2012). An analysis of USFS data in the Southern Rocky Mountain Ecoregion and Santa Fe Subregion finds that >70% of forest area receiving forest thinning treatment was >1km from the WUI and < 10% of treatment area within each region was within 250m of the WUI (DellaSala et al. 2024). Although this work concluded that most treatment was happening further from the WUI, it is not clear what proximity to WUI would be most effective for forest thinning to reduce wildfire risk to communities and infrastructure (DellaSala et al. 2024). Given political interest in managing IRAs differently due to WUI growth, understanding how WUI conditions influence fire conditions in IRAs (and *vice versa*) compared to other USFS designations is an important area for future research. Some economists suggest that protected lands like IRAs may encourage WUI growth (Lorah and Southwick 2003, Hjerpe and Aldrich 2018). Whether there are social-ecological relationships and feedbacks between IRA designations, WUI growth, fire conditions, and subsequent influences on IRA policies and WUI dynamics is unclear.

Some researchers argue that IRAs are insufficiently protected (DellaSala et al. 2024). Further, some researchers argue that fire conditions in IRAs may be reflective of fire trajectories that are recovering forest conditions to pre-colonial times (DellaSala et al. 2024, Johnston et al. 2021). The extension of this argument is that elevating the protection status of IRAs (e.g., to

Wilderness), and possibly increasing protections in other USFS lands could be beneficial for forest health (DellaSala et al. 2024, Johnston et al. 2021). But increasing protected status is generally associated with more restricted management and may not lead to desired ecological outcomes; for example, the authors of a study documenting a large mortality event of trees in Oregon's Malheur National Forest IRAs suggest that increasing thinning and burning treatments in forest stands will better prepare these forests for drought and pests (Johnston et al. 2025). Although Johnston et al. (2025) encourage increased forest management and not necessarily more road intrusion into forests, they suggest that added forests protections (e.g., elevating IRAs to Wilderness) could impair the ability of these forests to achieve forest management objectives.

Forests Pests

Increased risks to forest health from insects and pathogens is a key factor that is cited as justification for rescinding the roadless rule (90 FR 42179), but we uncovered little research that directly assessed pests and pathogens as a function of IRAs. One white paper argues that IRAs should not be intensively treated for beetle infestations, but this paper provides no direct research comparing IRAs to other designations (Black et al. 2010). An analysis of USFS Forest Inventory and Analysis (FIA) Program data finds no obvious relationship between road proximity and root disease; however, the analysis did quantify an elevated probability of invasive plant species' presence within ~150 m of roads (Healey 2020). Although the stated intent of Healey (2020) was to evaluate the efficacy of the Roadless Rule, it includes no direct comparison of disease or invasive species between IRAs and other USFS administrative units. We are aware of no other research that assessed invasive species and IRAs. A mass tree mortality event in IRAs within

Oregon's Malheur National Forest concludes that insects partially contributed to tree death (Johnston et al. 2025), but this research includes no comparisons to other USFS administrative designations. It is unclear whether the Roadless Rule played a role in the tree mortality compared to other potential causal factors in Malheur National Forest. Overall, the effects of the Roadless Rule on insect pests, pathogens, and disease are unknown, though proximity to roads tends to generally be associated with more introduced and pest species (Healey 2020, Parendes and Jones 2000, Mortensen et al. 2009, Ward et al. 2020).

Watershed Conditions

A key argument in establishing the Roadless Rule was that the prevalence of IRAs in major watersheds would provide benefits to watershed health and drinking water (66 FR 3244). This argument posits that IRAs have more intact hydrological and sedimentation structure and processes compared to federal forest lands with more roads. Research generally shows that forest roads disrupt the location and extent of overland water flow resulting in altered erosion and sediment input in streams (Kastridis 2020, Luce 2002). One analysis of > 15,000 watersheds uses the USFS "watershed condition framework" to compare federal forestlands across the U.S. (Anderson et al. 2012). This framework scores watersheds as 'properly functioning' or 'at risk' based on their "geomorphic, hydrologic, and biotic integrity relative to their natural potential condition." This assessment estimates that 80% of Wilderness land had 'properly functioning' watersheds and 18% had watersheds with functions 'at risk.' In comparison, 64% of IRAs had 'properly functioning' watersheds with 34% 'at risk' (Anderson et al. 2012). At the bottom end, only 38% of other (non-Wilderness and non-IRA) USFS lands had 'properly functioning' watersheds with 58% at risk (Anderson et al. 2012). We note that among the 12 variables that the USFS used to classify watersheds were roads and trails. Thus, these methods assume impacts from roads rather than necessarily directly measuring a water quality outcome.

Although there have been broader claims about water quality and economic benefits from IRAs (DellaSala et al. 2011a, b)), there is little research on IRA waters specifically that supports these claims. One recent study in western USFS lands suggested that increasing protections for IRAs would benefit drinking water protections, although the study did not quantify drinking water supplies on IRAs compared to other USFS lands (Law et al. 2021). Another recent study found 489 watersheds that are both important for drinking water provision and are currently over 50% covered by protected areas with GAP 1 or 2 (Talty et al. 2020). This number increases to 780 watersheds if IRAs are included with the more strictly protected lands, highlighting the role of maintaining IRAs under management that protects drinking water (Talty et al. 2020). Even though IRAs intuitively provide restrictions on activities that are known to impact watershed health and drinking water supplies, little research has directly assessed or quantified how IRAs have benefitted water quality and supplies.

The most recent analysis of IRA contributions to river protection provides more robust evidence for the Roadless Rule's drinking water provisions (Olden et al. 2026). This study assessed rivers where the Roadless Rule was the primary protection (compared to more protected designations like Wilderness or less protected designations like multiple use USFS lands) and rivers where IRAs contributed protection but other, stronger designations were in place. Olden et al. (2026) also focused on watersheds that were influenced by IRAs, either because at least 5% of the watershed's area was in an IRA or because the watershed was within 160 river km downstream of an IRA boundary. This study found that IRAs protect 2.5% of the conterminous U.S.' river length (131,316 km), with IRAs serving as the dominant protection mechanism for most of that river length. Although IRA river protections primarily occur in western states, IRAs protect large amounts of river lengths in eastern states which have generally lower levels of public land protection. IRAs contributed markedly to river protection in some states (e.g., 18.5% of river protection in Idaho, 8.2% in Utah, 7.0% in Colorado) (Olden et al. 2026). By analyzing watersheds that contribute to public water systems, Olden et al. (2026) show that 25 million people receive their drinking water from watersheds influenced by IRA protections. In some states, these protections are large. For instance, nearly a quarter of Californian public water system consumers and nearly 60% of Colorado's benefit from IRA protections. Overall, 1/3 of IRA-influenced watersheds rank within the top 25% of important drinking water supplies within respective states. Although more work is needed to understand the effectiveness of the Roadless Rule on water supplies and quality, the Rule continues to provide important contributions to river protection and drinking water supplies.

Economics

The Roadless Rule was in part predicated on saving costs on expensive road building and maintenance and avoiding timber projects that generated lower revenue compared to subsidized development costs (66 FR 3244). Even so, the Rule notes that some fire prevention costs may be more expensive in IRAs and that the rule would likely have consequences for some industries (66 FR 3244). As such, the economic consequences of the Roadless Rule are worth understanding. We note that economic studies relevant to the Roadless Rule are limited and often do not use the pseudo-experimental design we targeted. For instance, Clatterbuck (2007) uses a before-after comparison and Hjerpe and Aldrich (2018) conducted an economic valuation that drew on Wilderness data but did not directly compare IRAs to Wilderness or other federal forest lands quantitatively.

The Rule's adoption sparked research on the economic consequences of federal land protection (Wilderness, IRAs, National Parks, National Monuments) generally, with early work showing that counties with federally-protected land grew markedly faster (e.g., jobs, wages) than counties without such lands (Lorah and Southwick 2003). In response to initial Roadless Rule directives, a report offered rough estimates for the economic benefits provided by Roadless Areas' contributions to diverse values (e.g., hunting, recreation, biodiversity, property values) (Loomis and Richardson 2000). Although this analysis projected thousands of jobs and millions of dollars in benefits from the Rule, it is not necessarily comprehensive nor does it fully account for tradeoffs in the economic consequences for lost mineral and timber opportunities.

Impacts to timber jobs have been an ongoing debate surrounding the Roadless Rule's consequences (Hjerpe and Aldrich 2018). Other large shifts in management of National Forests to increase conservation, such as the 1994 Northwest Forest Plan, have impacted local economies, including trading off timber employment for a broader focus on forest restoration, firefighting, recreation, tourism, and non-timber forest products (Eichman et al. 2010, Charnley et al. 2019, Spies et al. 2019). Given this, further analysis on economic tradeoffs due to the Roadless Rule would be useful. The only study we are aware of to assess the Roadless Rule and timber harvest finds no national effect of the Roadless Rule on timber employment, although several counties experienced timber employment losses that were offset by gains in other regions (Clatterbuck 2007).

The limited economic research on IRAs suggests that the Roadless Rule contributes substantially to rural economies. For instance, IRAs provide billions of dollars in recreation and other values (direct uses, science/education, biodiversity, recreation) (Hjerpe and Aldrich 2018). Compared to counties without IRAs, rural western counties with IRAs have seen a net positive migration rate with the Rule, likely due to the economic opportunities provided by IRAs (Hjerpe and Aldrich 2018), although the frequent juxtaposition of IRAs near Wilderness makes it difficult to know whether Wilderness rather than IRAs are driving these patterns (Hjerpe et al. 2020). Beyond migration due to IRAs, one analysis finds that both Wilderness Areas and IRAs equally function as amenities that increase housing prices in New Mexico, providing 3.5% of the housing value in the state (Izon et al. 2010). In line with other research (Lorah and Southwick 2003, Hjerpe and Aldrick 2018), this may in part explain why WUI growth is increasing near IRAs and other federally protected areas. Notably, research on the economic effects of the Roadless Rule is relatively limited, largely older, and often offers little comparison to other federal land designations or counterfactual scenarios of changing the Roadless Rule.

Discussion

Research Needs

Our review exposes the value of more research on the effects of the Roadless Rule on multiple social and environmental sectors. There is a need both for quantifying differences across forest designations and for better understanding of the causes behind these differences. Such mechanistic understanding is necessary to predict the consequences of any future changes in designation, for example how these forest designations interact with intrinsic biophysical conditions to determine wildfire outcomes. Further, there are some critical issues like watershed condition and forest health that are poorly represented in the literature. We suggest that additional research address the effects of the Roadless Rule on water quality and quantity as well as the transmission of forest pests and pathogens.

Multi-disciplinary social science research would support understanding how the Roadless Rule compares to other land protections. For example, research on how communities engage with and value IRAs versus other USFS lands would be valuable. Indeed, some research suggests that people perceive IRAs as less ‘wild’ than Wilderness but more so than other USFS lands (Flanagan and Anderson 2008). The few economic studies we found indicate that the Roadless Rule provides important economic value, however, more in-depth analyses are needed to comprehensively examine how the Rule impacts and potentially benefits rural economies, particularly in comparison to other federal land designations. Protected areas like Wilderness and National Parks have contributed to ‘amenity migration’ where people move towards these landscapes for quality of life reasons (Hjerpe et al. 2020). However, the co-location of many IRAs with Wilderness Areas makes it difficult to evaluate whether IRAs have similar effects. Overall, there remains important uncertainty as to whether federal protections around IRAs have resulted in population, urban, and WUI growth near protected areas and, if so, what the impacts of that growth has been for the natural resources those federal lands were meant to protect (Lorah and Southwick 2003, Hjerpe and Aldrich 2018, Hjerpe et al. 2020).

Although analysis of USFS data shows that IRAs do indeed receive ecological restoration and forest resilience treatments (Healey 2020), it remains unclear if those treatments are happening at the pace, scale, and cost effectiveness needed to achieve forest health, wildfire risk reduction, and biodiversity protection goals. There is also value in quantifying if and to what extent IRA designations have limited or delayed forest management activities and what the consequences of this has been on forest health and species conservation issues. Finally, a valuable future research trajectory would be to understand whether fire regime departure occurs between IRAs and other USFS designations and how much wildfire characteristics reflect differences in wildfire management, fire suppression, and other actions.

Importantly, any change to the Roadless Rule - in part or in whole - would benefit from dedicated research on any resulting effects. Given the Roadless Rule is a massive natural resource policy experiment, changes in policy could be considered a new experimental treatment. Understanding the environmental and social consequences of those policy changes could inform future decisions. Additionally, given roadlessness is of global interest (Ibisch et al. 2016), there is value in understanding how lessons learned from the U.S. Roadless Rule experiment can translate to other geographies .

Policy Implications

The weight of the science synthesized here does not provide robust support for either loosening or increasing protections for Roadless Areas. Despite remaining uncertainties, research to date suggests that maintaining the Roadless Rule could provide a balance of rural economic benefits, responsible public investment for forest health and fire management, and flexible forest interventions for biodiversity and other conservation goals including watershed health and drinking water. Removing restrictions in Roadless Areas would expose the extensive biodiversity and recreational values in IRAs to known risks from road development and timber and mineral extraction (Trombulak and Frissell 2000, Ibisch et al. 2016, Kastridis 2020, Loomis and Richardson 2000). Further, it is not clear that revoking the Roadless Rule would improve wildfire management by increasing wildfire risk reduction treatments or suppression activities, which are already occurring in IRAs. Conversely, increasing protections for Roadless Areas would tend to enhance the policy durability of protections but may impair the ability of practitioners to implement management actions for conservation and fire objectives. This suggests that maintaining the Roadless Rule in its current form is likely most prudent to protect diverse public values. Even so, adjustments to the Rule may help advance natural resource management objectives and such adjustments would benefit from dedicated research to understand policy change implications and to inform the ongoing science-policy interface around the Roadless Rule.

Conclusions

The Roadless Rule is one of the most expansive natural resource policies in the U.S. and has spurred political debate for years (Holmes et al. 2022). Research has demonstrated the Rule's importance for biodiversity conservation over the past quarter-century since the Roadless Rule was established. Even though IRAs are not necessarily more biodiverse than lands like Wilderness, they provide protection to a large suite of unique habitats and species not protected by Wilderness or other higher-level designations. Our review finds that neither increasing nor decreasing protections in IRAs would likely improve USFS wildfire management objectives focused on reducing wildfire severity. Watershed impacts as well as forest pests and pathogens remain notably understudied, although IRAs influence drinking water supplies for millions of people. Finally, economic studies suggest that the Roadless Rule provides important value to rural economies, largely through recreational opportunities. Even so, economic research is relatively limited and warrants additional study, particularly around tradeoffs. Further, to our knowledge, there is little social science research on the consequences of the Roadless Rule on Indigenous peoples and other local communities. Given global interest in roadlessness (Ibisch et al. 2016), the social and ecological consequences of the Roadless Rule can inform roadless area management in other countries. The extent of unique biodiversity protections combined with the opportunity to advance ecologically beneficial thinning and prescribed fire provides an opportunity to maintain the Roadless Rule and further leverage its flexibility to drive diverse natural resource goals and innovation.

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Figures

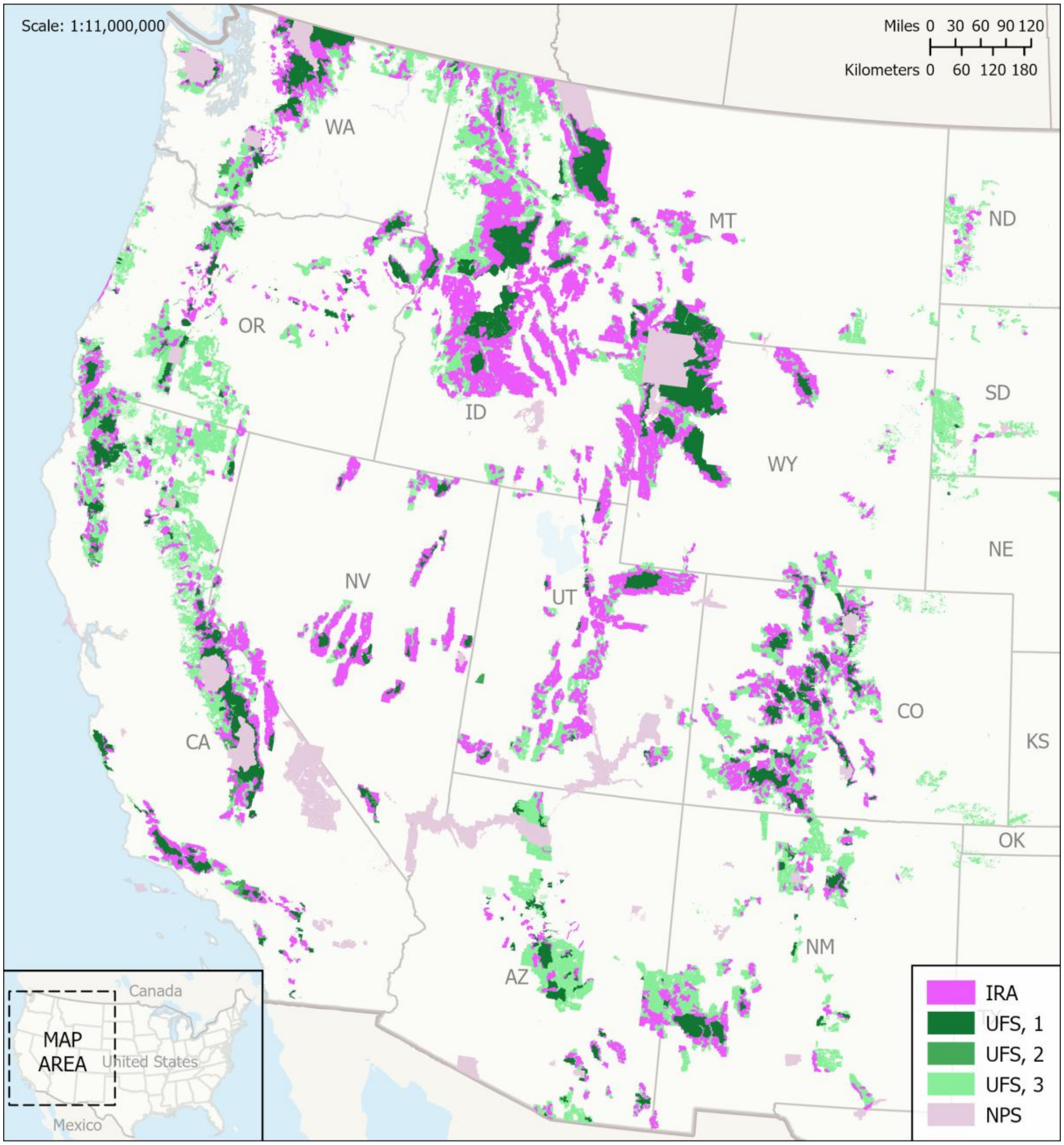

Figure 1. Distribution of Inventoried Roadless Areas (IRAs) with other US Forest Service (USFS) and National Park Service (NPS) lands in the western conterminous U.S. USFS lands are broken out by GAP status (1-3). Not shown are IRAs in the eastern conterminous USA or southeast Alaska.

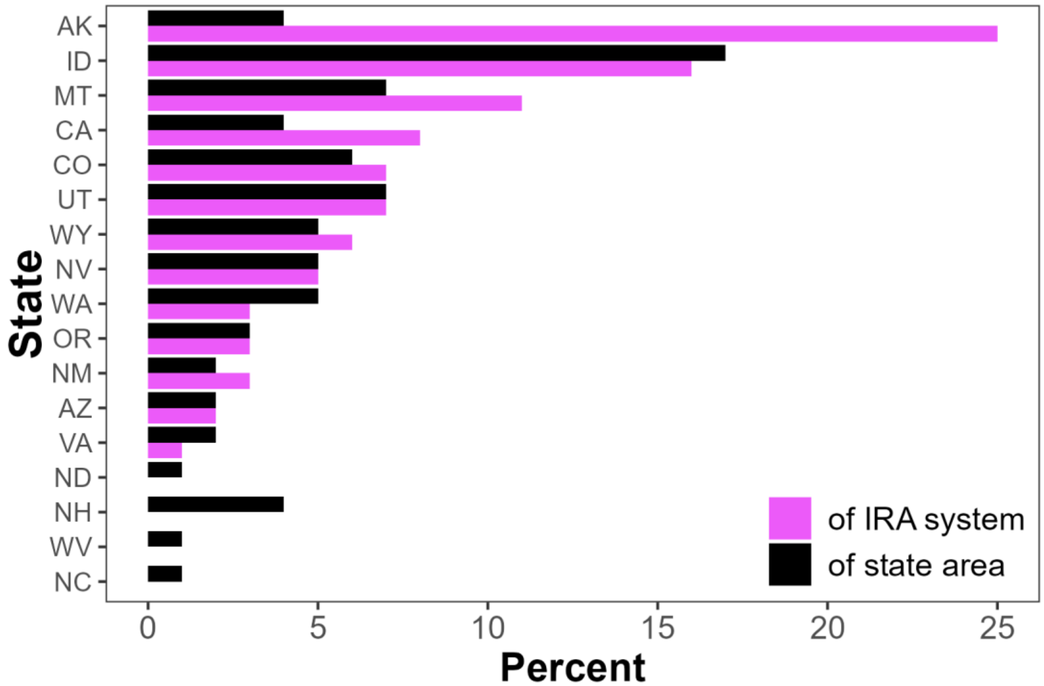

Figure 2. U.S. States which contribute to at least 1% of the Inventory Roadless Area system or where IRAs comprise at least 1% of a state's geographic area. These states cumulatively encompass 99% of the IRA acreage with several states contributing substantially to the IRA system. States are ordered by contribution to the IRA system.

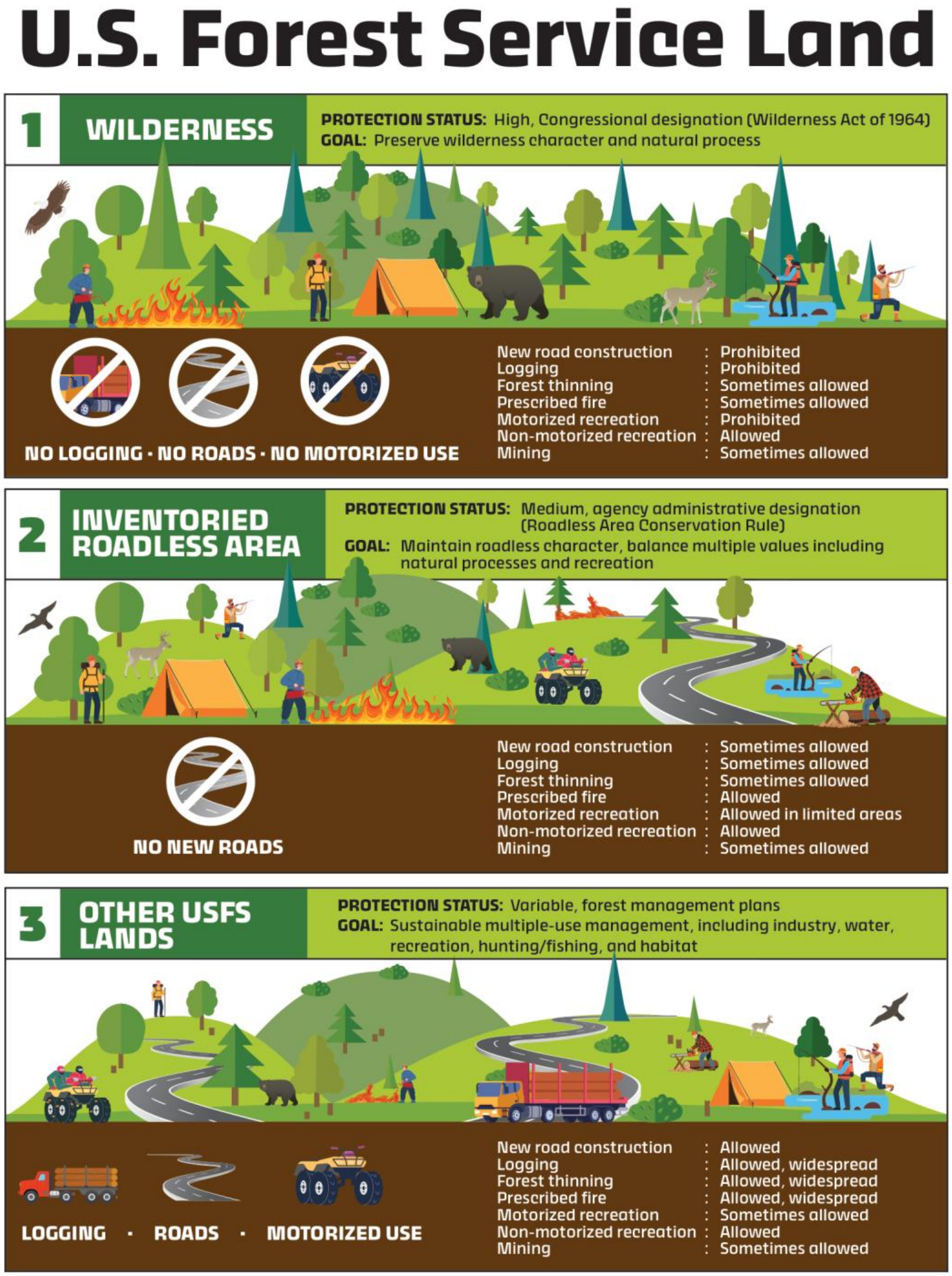

Figure 3. Major differences in goals and allowed uses among three administrative categories of U.S. Forest Service lands. Inventoried Roadless Areas represent an intermediate degree of protection and use compared to Wilderness (more protected, fewer used) and other USFS lands (less protected, more uses).

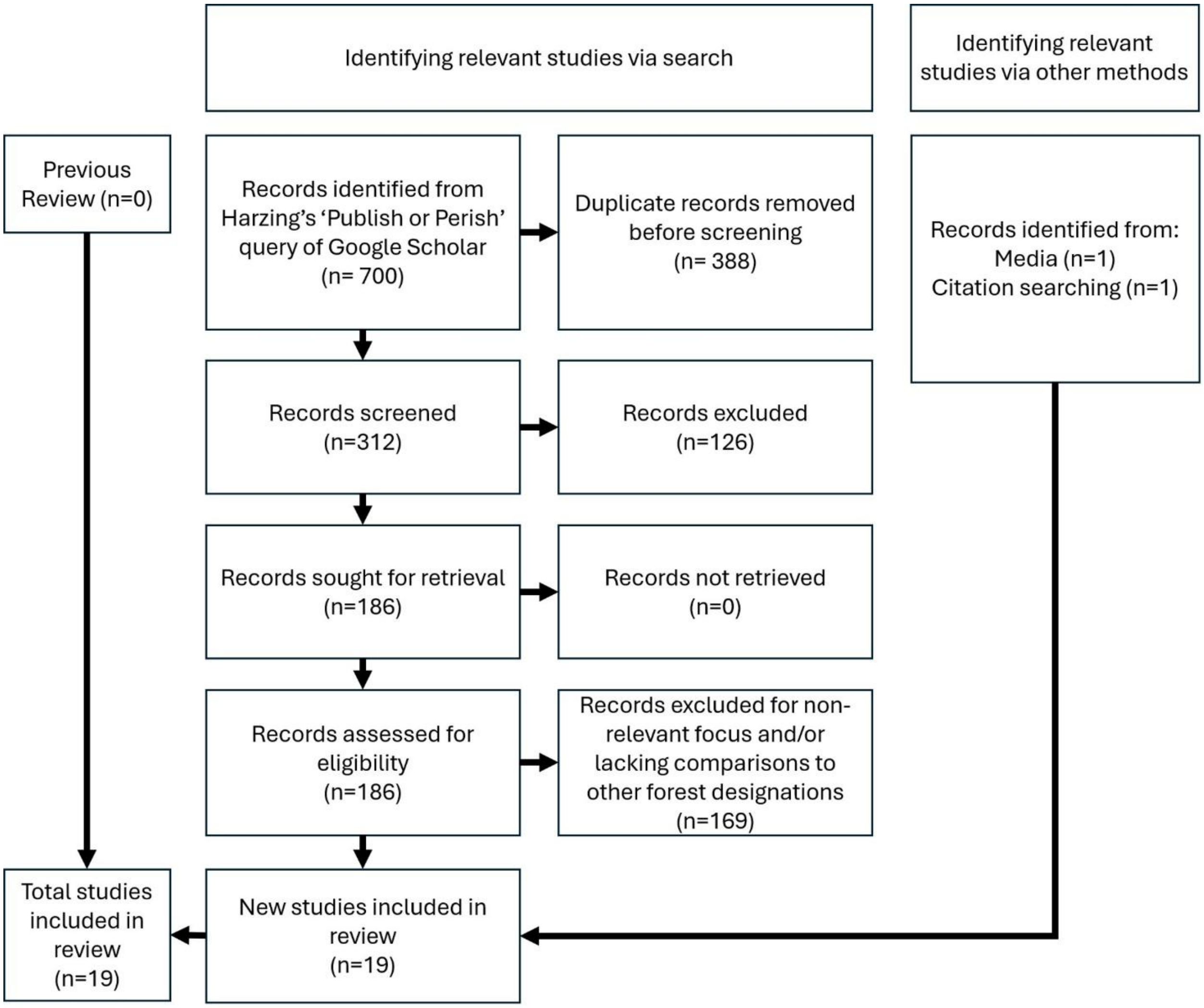

Figure 4. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram documenting the Roadless Rule review's workflow.

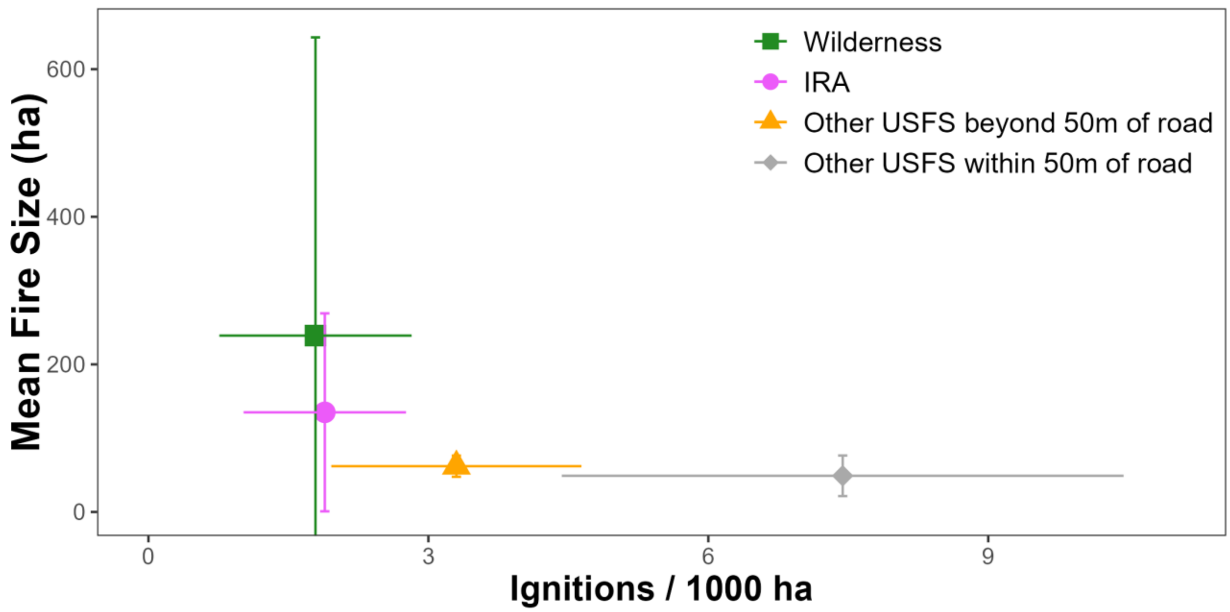

Figure 5. Tradeoffs between average ignitions rates and fire sizes across U.S. Forest Service lands by designation. Federal forest lands with greater protections and fewer roads have lower ignition rates but larger fires whereas ignitions are more common in more heavily roaded forest lands but fires are more readily extinguished and therefore smaller. Data and standard deviations adapted from Aplet et al. (2026).