Mature and Old-Growth Forest Contributions to Large-Scale Conservation Targets in the Conterminous USA

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Abstract: Mature and old-growth forests in the conterminous USA support exceptional levels of biodiversity but their area has declined substantially from over a century of logging and development. Conservation target setting has included proposals to protect 30%, 50%, and 100% of remaining mature forests on federal lands within strictly protected (GAP1, 2) reserves. We present results of the first coast to coast spatially explicit mature forest assessment by major forest types (n=22), landownerships (federal, state, private, tribal), and GAP status (1-4) useful in conservation target setting. We overlaid mature forests with the NatureServe's Red-listed Ecosystems and species, above-ground living biomass, and drinking water source areas to assess their conservation values. Mature forests total ~67.2M ha (35.9%) of all forest development stages that are scattered across 8 regions with most mature forests located in western regions. All federal lands combined represented the greatest (35%) concentrations of mature forests, ~92% of which is on the national forest system with ~9% on Bureau of Land Management (BLM) and

~3% on national park lands (some minor mapping errors in the datasets). Mature forests on national forest land supported the highest concentrations of conservation values. National forests and BLM lands each have only ~24% of mature forests in GAP1,2 (5.9 M ha) status. The vast majority (76%, 20.8M ha) of mature forests are at-risk to logging on federal lands that store 10.64 Gt CO_2 (e). If these forests were logged over a decade, there would be an estimated ~1 ppm increase in atmospheric CO_2, which is significant on a global scale. We recommend upper bound (100%) protections for remaining federal mature forests, including elevating the conservation status of Inventoried Roadless Areas. Protecting mature forests on federal lands would avoid substantial CO_2 emissions while allowing continued carbon sequestration to act as natural climate solutions in compliance with the Paris Climate Agreement and two presidential executive orders on forests and land protections. On non-federal lands, which have fewer mature forests, regulatory improvements and conservation incentives are needed.

Key Words: conservation targets, conterminous USA, mature forests, old growth

1.0 Introduction

Forest conservation in the USA has for decades centered on protection and ecological restoration of forests in the later stages of stand development because of their irreplaceable biodiversity and ecosystem services (e.g., Davis 1996, Strittholt et al. 2006). Terms like primary forest, late-successional forest, mature forest, old-growth forest, and ancient forest are routinely used, sometimes interchangeably (Mackey et al. 2014). However, standardized metrics for national-scale inventory and conservation target setting for these forests are lacking.

Precisely when a forest is considered to be in the later structural development stages depends on many diagnostic features such as the age, height, and diameter-at-breast height of the dominant-codominant trees; canopy and understory complexity (vertical and horizontal layering); large standing dead (snags) and down trees (logs); and large trees with broken and highly branched tops. The age at which forests acquire these characteristics varies biogeographically, among forest types, climate and natural disturbances, and site conditions (e.g., productive vs slow growing sites). Gap-phase dynamics, the result of tree death (singlular or in cohorts), is the predominant disturbance event in older forest stands along with blow-down especially along exposed edges and ridgelines. When this occurs, the resultant increased light and nutrient levels within canopy gaps release suppressed trees in the understory to fill the gaps over time (e.g., in the Pacific Northwest, Spies 2004, Franklin and Van Pelt 2007; eastern forests, Davis 1996). The lack of severe stand-level disturbances over extended periods allows trees to acquire impressive stature and old ages associated with increasing biological complexity.

Old-growth forests generally have exceptional levels of biodiversity compared to logged forests (Luyssaert et al. 2008, Keith et al. 2009, Lindenmayer et al. 2012, 2014; Cannon et al. 2022). However, because of the timber value of older trees they are on the decline globally (Lindenmayer et al. 2012, 2014, Mackey et al. 2014). The loss of old-growth forests is coupled with changes to the global climate (Lawrence et al. 2022), reducing opportunities for natural climate solutions (Griscom et al. 2017, Moomaw et al. 2019). In the USA, the conservation values of old-growth forests have been recognized in every forested region, including Alaska (DellaSala 2011, Orians and Schoen 2012, Vynne et al. 2021, DellaSala et al. 2022), Pacific Northwest (Strittholt et al. 2006, Krankina et al. 2014), West (Rockies, Pacific Southwest, Southwest collectively: Kauffman et al. 1992, 2007), Central (Shifley et al. 1995), Great Lakes

(Carleton 2003), Southeast (Hanberry et al. 2018), and Northeast (Davis 1996, Leak and Yamasaki 2012, Ducey et al. 2013).

The importance of old-growth forests can also be described along a spatial gradient from individual trees within a stand to their role in watersheds and landscapes. At the tree level, the largest trees in old-growth forests may represent just 1% of all stems yet store at least 40% of the above-ground carbon as carbon stock increases with size as trees age (Stephenson et al. 2014, Lutz et al. 2018, Mildrexler et al. 2020). At the stand level, old-growth forests store 35 to 70% more carbon, including in the soils, compared to logged stands (Keith et al. 2009, Mackey et al. 2014, Mayer et al. 2020). Old-growth forest stands may also act as a buffer against extreme climate conditions (DellaSala et al. 2015, Frey et al. 2016, Betts et al. 2017). At the watershed level, old-growth forests maintain hydrological cycles (DellaSala et al. 2011, Perry and Jones 2016, Crampe et al. 2021). In the Pacific Northwest, old-growth forests may function as fire refugia in large wildfire complexes (Lesmeister et al. 2021).

Aside from select portions of the West, most old-growth forests in the conterminous USA were eliminated decades ago as logging and development proceeded from east to west coast. What remains is largely on federal lands where the government has untapped policy options for stepped-up conservation. Some of the remaining old-growth forests on national forest land are within Inventoried Roadless Areas (IRAs) that are at least 2,000 ha. Road building and most forms of logging and development are prohibited within IRAs but only administratively and not by an act of Congress, meaning protections are not inviolate or permanent (i.e., classified as GAP3 multiple use status, see methods). Importantly, significant portions of eastern forests are approaching maturity (100+ years, Gunn et al. 2013) on federal lands. As these mature forests recover from historical logging, they could develop old-growth structure within decades. For our study, we are using estimates of forest structure that correlate with advanced stand development collectively referred to as "mature" to capture both the stage that is not quite old growth and the old-growth stage as well. We consider old growth a subset of primary forest that lack commercial logging or other industrial-scale developments (Mackey et al. 2014).

Primary and old-growth forests generally have received increased attention as natural climate solutions (DellaSala et al. 2020, IUCN 2021, Law et al. 2021), including from policy makers (e.g., https://ktvz.b-cdn.net/2022/02/2022-02-17-DOI-and-USDA-Old-Growth.pdf; March 22, 2022) and conservation non-governmental organizations (NGOs) (https://www.climate-forests.org/; https://forestcarboncoalition.org/; accessed May 15, 2022). Article 5.1 of the Paris Climate Agreement calls on governments to protect and enhance "carbon sinks and reservoirs," while Article 21 of the UNFCCC COP26 Glasgow Climate Pact emphasizes "the importance of protecting, conserving and restoring nature and ecosystems, including forests… to achieve the long-term global goal of the Convention by acting as sinks and reservoirs of greenhouse gases and protecting biodiversity…" (UNFCCC 2021). Furthermore, the United States was one of 140 nations at COP26 that pledged to end forest degradation and deforestation by 2030 (United Nations 2021). Also, the Summary for Policy Makers (SPM.D.4) in the Intergovernmental Panel on Climate Change (2022) report mentions safeguarding biodiversity and ecosystem integrity as fundamental to climate resilient developments. Attention to mature and old-growth forests can inform implementation of these policy commitments.

Large-scale conservation proposals for all land and water types have increasingly relied on 30 percent (i.e., 30% protected by 2030 or 30 x 30; Dinerstein et al. 2019, Carroll and Noss 2021, Carroll and Ray 2021; Law et al. 2021; Law et al. 2022; One Earth Global Safety Net - https://www.oneearth.org/the-global-safety-net-a-blueprint-to-save-critical-ecosystems-and-stabilize-the-earths-climate/; accessed May 28, 2022) and 50 percent (or Half Earth) protection targets involving triage approaches (Noss et al. 2012, Wilson 2016). Notably, President Joe Biden issued an executive order directing federal agencies to develop 30 x 30 targets for all lands and waters (White House 2021). A more recent executive order from the President directed federal agencies to inventory and assess threats to mature and old-growth forests nationwide for possible protections (White House 2022). Regionally specific proposals, such as the 79M ha of proposed protected areas in a five state area (OR, WA, ID, MT, WY; Bader 2000), a portion of which includes wilderness additions in the Northern Rockies Ecosystem Protection Act (S.1276), have not been assessed for mature forest contributions. Thus, it is vital that mature forests are clearly defined, assessed, and mapped at multiple spatial scales (regional to national) to advise decision makers and NGOs on how best to meet climate and biodiversity commitments and targets.

The objectives of our paper were to examine the contribution of mature forests in the conterminous USA to: (1) conservation of at-risk forest ecosystems and species based on IUCN Red List criteria (Comer et al. 2022); (2) source catchments for drinking water (Mack et al. 2022); (3) above-ground living biomass; and (4) contributions to meeting 30% (Dinerstein et al. 2019), 50% (Noss et al. 2012, Wilson 2016), and 100% protection targets nationally and in select regions.

2.0 Methods

2.1 Forest Mapping

We generated a map of mature forests for the conterminous USA based on a recently completed assessment of all forest development stages (least to most structurally developed) at 30-m pixel resolution (i.e. a spatial data set) totalling some 187M ha (Mackey et al. in review). In that study, pixels were first stratified by EPA Level III ecoregions and major forest types (Ruefenacht et al.2008). Relative forest maturity was then mapped based on classifying the stratified pixels into 10 ranked ordinal classes based on estimates of forest canopy cover density, forest canopy height, and above-ground living biomass. Details of source data and spatial analytical work flows are provided in Mackey et al. (in review). For this study we defined mature forest as comprising the top three classes of relative forest maturity that can be spatially derived using remote sensing datasets.

2.2 Land Ownership and GAP Status

The extent, management, and protection status of mature forest was assessed using spatial data provided by government agencies. We used the forest ownership dataset produced by Sass et al. (2020) for the USDA Forest Service based on 2017 data. Each ownership category was used as a mask to determine the extent of mature forest within different tenures across the conterminous USA. The only additional aggregation made was the combination of the two FIA 41 categories, TIMO/REIT and Private that were combined into a single masking layer. The Gap Analysis Projet (GAP) management status was applied to mature forest using the PAD-US Spatial Analysis Data provided by USGS (2020). GAP 1 (e.g., Wilderness, National Parks) and GAP2 (e.g., National Mounments) were considered protected lands. GAP3 was multiple use management and GAP4 was no protection. The flattened version of the dataset were an important component of the analysis for determining the protected status of forests. Inventoried roadless areas (IRAs) were filtered from the dataset and classified in our study as GAP2.5– that is – even though IRAs are given GAP3 status in the PAD-US dataset, we gave some credit to IRAs for administrative protections from most forms of logging and development. To ensure consistency among datasets, we compared the IRA layer to the 2001 Roadless Rule Feature layer provided by the USDA (https://data-usfs.hub.arcgis.com/datasets/usfs::roadless-areas-2001-roadless-rule-feature-layer-mature/about) for cross validation. We also assessed additional ownership and management of mature forests including National Forests (National Forest System Land Units, https://data.fs.usda.gov/geodata/edw/datasets.php), National Parks (https://irma.nps.gov/DataStore/Reference/Profile/2224545?lnv=True) and BLM (Derived from PAD-US https://www.usgs.gov/programs/gap-analysis-project/science/pad-us-data-download). The metadata (https://www.fs.usda.gov/rds/archive/products/RDS-2020-0044/_metadata_RDS-2020-0044.html) for landownerships did create some minor overlap problems where IRAs were inadvertently present in the dataset as within other ownerships even though this designation applies only to national forests. Those are recognized in each of the applicable tables as IRA misclassifications. The five western state regional example (79M ha) that includes the Northern Rockies Ecosystem Protection Act was mapped after Bader (2000).

2.3 Biomass Calculation

To determine the estimated amount of above-ground living biomass stored within mature forests, spatial data produced by Harris et al. (2021) was used as an input layer. Calculating the amount of biomass involved firstly warping the dataset to ensure a 30-m pixel size using GDAL and later masking to the extent of determined mature forest. The R program exactextractr was then utilized to sum the total amount of biomass within the forests. Due to the discrepancy between the input data being at a 30-m resolution and scaled to Mg/ha, the total value was then converted to produce overall biomass weight in tonnes.

2.4 At Risk Forest Ecosystems and Species

The IUCN Red List of Ecosystems (RLE) is an emerging global standard for ecosystem risk assessment that integrates data and knowledge to document the relative risk status of ecosystem types. RLE criteria were used to assess 655 terrestrial ecosystems in temperate and tropical North America, including 182 forest and woodland ecosystem types in the conterminous USA using the U.S. National Vegetation Classification (Comer et al. 2022). We mapped these ecosystem types nationally using inter-agency LANDFIRE (2016) map products at 30-m pixel resolution with remote sensing data from approximately 2011. The RLE indicators that gauge the probability of range wide ecosystem collapse were measured for each criterion to address: trends in ecosystem extent (A); the relative restricted nature of its distribution (B); and the extent and relative severity of environmental degradation (C); and the extent and relative severity of disruption of biotic processes (D). Based on these measures, we categorised ecosystems as Collapsed, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient, or Not Evaluated. Some 119 (65%) of the 182 USA forest ecosystem types were listed as threatened in some form (i.e., either Critically Endangered (CR) [6.5%], Endangered (EN) [24%], Vulnerable (VU) [24%] or Near Threatened (NT) [10%]).

We also overlaid our mature forest map with the modelled distributions of the threatened forest and woodland types to quantify their relative representation within managed and protected lands.

2.5 At-Risk Forest-Associated Species

We used a database containing an analysis of the habitat requirements for species of conservation concern, including their co-occurrence with standard ecosystem classification units and vegetation structural attributes (Reid et al. 2016). This database includes over 6,000 plant and animal taxa known to occur throughout the conterminous USA. At-risk status was provided using both NatureServe conservation status ranks (Stein et al. 2000) and for listing status under the US Endangered Species Act (i.e., for species listed as Threatened or Endangered, as well as Candidate or Proposed). We documented relationships through map overlays of species locations with mapped ecosystem type distributions. While incomplete, mapped distributions of forest types provide an initial indication of where mature forests may support at-risk forest-associated species.

2.6 Drinking Water Source Areas

The USDA Forest to Faucets assessment provides a relative index summarizing the importance of forested land for the provision of surface drinking water based on biophysical and demographic data (Mack et al. 2022). These data were made available at the scale of subwatersheds delineated by the USGS, of which there were approximately 100,000 in the USA (USGS USDA NRCS 2013). We masked these data by the mature forest pixels to provide a spatial layer showing the relative importance of mature forests to surface drinking water. We also calculated mature forest area for four classes representing each quartile of the relative importance to surface drinking water index and summarized by area for each GAP status and land tenure. Classes ranged from 1 (lowest importance, 0-25% relative importance) to 4 (highest importance, 76-100% relative importance) based on the relative importance to surface water index defined by the USDA Forest Service.

3.0 Results

3.1 Mature Forests Spatial Extent

We estimate that there are currently 67,183,015 ha (35.9% of all structure classes) of mature forest in the conterminous USA (Figure 1). Mature forests are scattered across eight forested regions, including the Pacific Northwest (1), Pacific Southwest (2), Rockies (3), Southwest (4), Great Lakes (5), and Southcentral (6), Northeast (7), and Southeast (8). Regional zoom-ins further reveal concentrations in those areas (Figure 2).

Figure 1 goes here

Figure 2 goes here

We provide example photographs of mature forests for some major forest types of the conterminous USA for context and to illustrate some characteristic structures (Figure 3A-F).

Figure 3A-F goes here

Using the western states regional example, mature forests represent ~7.60M ha (9.6%) of the 79.1M ha within the five-state area that includes the Northern Rockies Ecosystem Protection Act under consideration in the US Congress for protection (Figure 4). Notably, only 20% of the mature forests are in GAP1 and 2 status with 30% in IRAs having intermediate protections (GAP 2.5) (Table 1), meaning the vast majority of this area is vulnerable to development pressures.

Figure 4 goes here

Table 1 goes here

3.2 Mature Forest by Major Forest Types

Mature forests were located within 22 forest groups spanning conifer and hardwood types in the conterminous USA (Table 2). Nearly all mature forest types had their greatest percentages in unprotected status (GAP3, 4; no classifications) with only 14.7% overall in GAP1 and 2 and 7.1% in GAP2.5. Only two forest types, Fir (*Abies* sp)/Spruce (*Picea* sp)/Mountain Hemlock (*Tsuga mertensii*) (33.1%) and Other Western Softwoods (41.3%) met the lower bound (30%) target. Percentages would improve for several forest groups if IRAs (GAP2.5 status) received higher protection status via stepped-up protections. Notably, the FIA classifications inappropriately lump longleaf (*Pinus palustris*) with slash pine (*Pinus elliottii*)-dominated communities as one equivalent type thereby obscuring the conservation status of longleaf pine. For instance, there are five distinct longleaf pine ecosystem types mapped nationally and assessed under the IUCN Red Listing criteria (Comer et al. 2022), with two listed as Critically Endangered, and three as Endangered that do not show up on the FIA dataset.

Table 2 goes here

3.3 Mature Forest by Land Ownership and GAP Status

Federal lands (36%) have the highest proportion of mature forest, of which, National Forests have most (~92%) of the federal total (Table 3). Approximately 24% of mature forests on the national forest system were in GAP1 and 2 (Table 3). An additional 22% of mature forest was within IRAs (GAP2.5). If IRAs received elevated conservation status (e.g., increased to GAP2) that would increase mature forest protections in National Forests to 46%, which is within reach of the mid-level 50% target. Table S1 has a breakdown of mature forests by GAP status for every national forest.

Table 3 goes here

Remaining mature forests on federal lands were on National Parks (~3%) and BLM (~9%) (categories overlap some due to mapping errors in the datasets). BLM lands in particular are mostly nonforested areas with the exception of some areas like in southwest Oregon. However, like National Forests, only ~24% of mature forests on BLM lands have GAP1 and 2 status (Table 3). Of non-federal lands, mature forests were highest on Family private (55%) and lowest on Tribal (~4%). Interestingly, State lands (41%) were the only non-federal owner where a minimum 30% target was achieved but they did not have much mature forest overall. All other non-federal tenures were well below even the lowest 30% target.

Table 3 goes here

3.4 Mature Forests and Above-Ground Living Biomass

Aggregate above-ground living biomass values are by far highest on national forests, which represent 92% of the total federal and 45% of the total above-ground living biomass for all ownerships (Table 4). For non-federal lands, Family private has the most (52%) above-ground living biomass and Tribal (4%) the least. Notably, the ratio of carbon to above-ground living biomass is typically taken to be 0.5 (i.e. about 50% of the dry weight of biomass is carbon) though globally the ratio can range from 0.4-0.6 (Keith et al. 2010).

Table 4 goes here

3.5 Mature Forests and RLE Ecosystem Status

Of the 182 forest and woodland ecosystem types assessed with criteria from the IUCN Red List of Ecosystems in the USA, 119 (65%) were categorized from near threatened (NT) to critically endangered (CR); collectively considered here as "threatened" (Figure 5). The 102 types categorized as vulnerable (VU) through critically endangered (CR) occurred on 38% of current forest area. Critically endangered and endangered forest ecosystems were concentrated in the eastern states; mostly in areas with the longest and most intensive land use histories. Types found there included Southeastern Interior Longleaf Pine Woodland, Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland, and West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland (Table S2). Forest type descriptions are maintained for public access on NatureServe Explorer.

Figure 5 goes here

Large proportions of mature forest under GAP1 to GAP 3 status include types categorized by the IUCN RLE as Least Concern (Table 5). About 39.4M ha (394,000 km^2) of all at-risk (NT-CR) forests and woodlands occurred within area mapped as mature forest. While current area of critically endangered forests was quite limited overall, most at-risk forest mapped as mature forest was categorized as Near Threatened, Vulnerable, or Endangered. These were commonly located on either federal land, predominately national forests, or Family private (Table 5). Importantly, ~12.1M ha (18%) of mature forests with threatened status were located within GAP3 status under multiple use management. These were, for example, North Pacific Maritime Mesic-Wet Douglas-fir (*Psedutosuga menzeisii*)-Western Hemlock (*Tsuga heterophylla*) Forest (VU) in the Pacific Northwest, and Southern Rocky Mountain Ponderosa Pine Woodland (VU) in the southern Rocky Mountains (Figure 5). The other large proportion of mature threatened forest occurred on Family private land, mostly throughout the eastern states (Figure 5). Examples included Ozark-Ouachita Dry Oak Woodland (EN), Allegheny-Cumberland Dry Oak Forest and Woodland (EN [VU-EN]), or Southern Piedmont Mesic Forest (EN [VU-EN]).

Table 5 goes here

3.6 Mature Forests and At-risk Species

Using documented relationships between species of concern and forests, there were 97 mapped forest ecosystem types known to support these species (Table S3). Individual at-risk species associated with specific forest types were listed and maintained for public access on NatureServe Explorer website. Within these 97 types, mature forest was 29.2M ha. Species considered "at-risk" using NatureServe conservation status ranks included Vulnerable (G3), Imperiled (G2) or Critically Imperiled (G1) (Stein et al. 2000). From 1 to 64 of these species were associated with these 97 forest types. Among those with the most extensive mature forest included, for example, Laurentian-Acadian Northern Hardwood Forest (37,644 km^2 and 12 at-risk species), South-Central Interior Mesophytic Forest (16,046 km^2 and 50 at-risk species), and Southern

Appalachian Oak Forest (10,190 km^2 and 48 at-risk species) (Table S3). Using US Endangered Species Act (i.e., Threatened or Endangered, as well as Candidate or Proposed) as a measure of at-risk species status, numbers of species documented for their association to these 97 forest types ranged from 1 to 15 at-risk species. Among those supporting >1 at-risk species and with the extensive area in mature forest were, for example, North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest (10,370 km^2 and 4 at-risk species), East Gulf Coastal Plain Large River Floodplain Forest (4,295 km^2 and 13 at-risk species), and Atlantic Coastal Plain Blackwater Stream Floodplain Forest (2,417 km^2 and 8 at-risk species) (Table S3).

Of the 97 forest ecosystem types with habitat relationships documented for at-risk species, 70 were considered threatened (IUCN NT, VU, EN or CR) themselves. Threatened forest types support at-risk species (based here on NatureServe Conservation status ranks) with the most extensive area mapped as mature forest in South-Central Interior Mesophytic Forest (EN) (16,046 km^2 and 50 at-risk species), Northeastern Interior Dry-Mesic Oak Forest (EN) (15, 327 km^2 and 12 at-risk species), and Southern Appalachian Oak Forest (VU) (10,190 km^2 and 48 at-risk species) (Table S3).

3.7 Mature Forests and Drinking Water

Based on the USDA drinking water source area dataset, mature forests with the highest drinking water value (Class 4) were mostly on Federal lands with surprising large areas on Family Private and Corporate Private (Table 6). Importantly, a substantial (4.5M ha, >39%) amount of the highest quality drinking water comes from mature forests in GAP3 and 4 status, and much more (12.1M ha) is outside GAP status all together. Any loss of these forests due to logging and development would potentially impact drinking water supplies.

Table 6 goes here

4.0 Discussion

4.1 Mature Forest Spatial Analysis

Pan et al. (2011) used 2006 FIA plot data at 1-km resolution to produce an age class map of North American forests. However, our inventory provides a baseline map for tracking future changes in ecological development and management of mature forests at 30-m resolution that can be updated as new datasets and advancements in monitoring technologies become available. We estimate 67.2M (~36% of all structural classes) of mature forests are distributed across eight geographic regions that provide options for national and regional conservation. For the most part, these forests are not contiguous blocks as they are nested within a highly fragmented matrix of less developed structural classes (see Heilman et al. 2002) that has created an overall national deficit in mature forests, particularly intact blocks at least as large as IRAs.

4.2 Federal Land

Combined federal lands represented ~35% of the total mature forest structural classes with most (~92%) on national forests and a fraction managed by National Parks (~3%) and BLM (9%). Mature forests on federal lands support the highest concentrations of above-ground living biomass, at-risk ecosystems and species, and drinking water source areas. Despite their relative climate mitigation and biodiversity values, only 24% of mature forest on national forest and BLM lands are fully protected, which is below even the lowest bound 30% target. Our analysis supports 100% of federal mature forests for inclusion in protected areas. However, a scenario of the reverse situation, where all at-risk mature forests in GAP2.5 and GAP3,4 status are logged and then regrown, can be assessed in terms of the estimated projected emissions and effect on the atmospheric CO_2 concentration. This comparison would allow the mitigation benefit of avoiding such logging to be evaluated. For instance, at-risk mature forests on federal lands currently store ~5.8 Gt of above-ground living biomass (Federal land GAP 2.5 + 3 +4; Table 4), which is equivalent to 10.64 Gt CO_2. The effect of the emissions due to logging on elevating the atmospheric CO_2 concentration can be estimated as the carbon stock remaining in the atmosphere as the airborne fraction of the emissions by 2030 (after 8 years) and 2050 (after 28 years). These decades were chosen to comply with global emissions reduction targets and for assessing the mitigation potential of full protection.

The fraction of the airborne CO_2 from a pulse of emissions that decreases over time can be calculated from the natural land and ocean sinks and the regrowth of the forest (Keith et al. 2022). By 2030, 74% of the logging emissions would remain in the atmosphere, and by 2050, 54% would remain. The carbon stock that would be emitted by logging at-risk mature forests within a decade is ~10.64 Gt CO_2., This carbon stock can be converted to parts per million by volume (ppm) as the common unit to express atmospheric CO_2 concentration (1ppm = 7.8 Gt CO_2 (CIDAC, accessed June 12, 2022). If 74% of the CO_2 emitted remains in the atmosphere by 2030, then 10.54 Gt CO_2 emissions are required to raise the atmospheric CO_2 concentration by 1ppm. Thus, emissions of 10.64 Gt CO_2 would result in ~1 ppm increase in atmospheric CO_2 concentration by 2030 and 0.74 ppm by 2050. We note that an accelerated increase in logging is not unrealistic, as the Trump administration issued an executive order in 2019 to increase logging by 31% on national forests, which at the time equated to 2.2 million ha with no time frame specified (https://www.washingtonpost.com/energy-environment/2019/01/14/trumpsexecutive-order-will-cut-more-forest-trees-some-publics-tools-stop-it/; accessed June 12, 2022). Additionally, legislation is routinely introduced in Congress to greatly increase federal lands logging with few environmental protections (e.g., https://www.congress.gov/bill/115th-congress/house-bill/2936/text/ih?overview=closed&format=txt). Conversely, protecting at-risk mature forests would avoid a decadal logging equivalent of ~1 ppm CO_2 (10.64 Gt CO_2), which would make a meaningful mitigation contribution on a global scale if mature forests in the USA were instead protected as natural climate solutions (Griscom et al. 2017, Moomaw et al. 2019, Keith et al. 2022). It is this current decade that is critical for mitigation actions to avoid emissions and not to add to the atmospheric CO_2 concentration.

The IRA component of mature forests represents what remains of intact blocks on national forests. Elevating the conservation status of IRAs to GAP2 would increase mature forest protections on national forests to that approaching the mid-bound (50%) target. However, that would take either an act of Congress or administrative changes that remove exemptions for logging and other development projects (e.g., hydroelectric development, mining) along with new regulations making it more difficult to overturn roadless policies in general. The national roadless conservation rule has sustained 14 legal challenges upheld in appellate courts, was overturned twice on the Tongass National Forest in Alaska by pro-development administrations (i.e., George W Bush and Donald Trump), and was substantially changed by state petitions to the federal government in Idaho and Colorado. Thus, increasing administrative or congressional protections is key to elevating the conservation status of IRAs so they can be considered at least GAP2. While there is no comparable roadless policy for BLM lands, mature forests could be nominated to the National Landscape Conservation System (https://www.blm.gov/programs/national-conservation-lands; accessed May 15, 2022). The BLM oversees 14M ha of mostly iconic lands and waterways designated by Congress or presidential executive order mainly for conservation purposes that includes national monuments and other protective designations.

4.3 Regional

Federal forests in the Eastern region are maturing from logging that eliminated all but a fraction (1-2%) of the old-growth forests over a century ago (Davis 1996). Despite this, the USDA Forest Service (2022) revised its 20-year forest management plans for the 416,000 ha Nantahala and Pisgah National Forest in western North Carolina claiming that they needed to log mature forests to create a diversity of seral stages even though classic old-growth forests are still well below historical levels (Davis 1996). Additionally, under the Trump administration, the USDA Forest Service removed protections for large diameter (>50 cm dbh, up to 150 y old) trees on national forests in eastern Oregon and Washington that were in place for over two decades, even though large trees remain below historical levels (Mildrexler et al. 2020). Notably, the five state western proposal that includes the Northern Rockies Ecosystem Protection Act contains nearly 11M ha of mature forests with only 20% in GAP1 and 2 status and another 30% in IRAs (GAP2.5). These recent policy and management decisions underscore the importance of increasing mature forest protections regionally and nationally.

4.4 Nonfederal lands

Family forest owners are a group of nearly 10 million families, trusts, and estates representing the largest landowner category in the USA with one-third of the total forest ownership (von Heddeman and Schultz 2021). Substantial area of at-risk ecosystems, at-risk species, and drinking water also occur on these lands mostly in the eastern states. Family landowners generally tend to manage their forests for aesthetics, wildlife, conservation, and family ownership legacy. Thus, opportunities exist for conservation investments (Butler et al. 2016).

State lands are under state regulatory authorities, which aside from state parks, grant preference to intensive forest management over forest protections. Large corporate landowners manage forests mainly to maximize the return-on-investment by cutting trees when they approach culmination of mean annual increment (just before they reach maturity). Mature forests therefore are often looked at as a financial liability to be converted into fast growing monocultural plantations on short-rotation cycles. Many tribal lands also have timber objectives.

In general, for all non-federal lands, a combination of regulatory improvements and incentives could retain more mature forests (Dreiss and Malcolm 2021). This might include conservation easements, fee-title acquisitions, and carbon offsets that result in verifiable conservation gains over status quo management. Notably, our mature forest assessment may provide procurement guidance to the private sector regarding avoiding logging in older forests, as, for example, a recent shareholder resolution at the Home Depot chain to purchase wood not coming from old-growth forests (https://ir.homedepot.com/~/media/Files/H/HomeDepot-IR/2022/2022%20Proxy%20Statement%20-%20Final.pdf; accessed May 20, 2022).

4.5 Data Limitations

The mature forest map used here includes all the data limitations and model assumptions reported in Mackey et al. (in review) including: the source spatial data used to derive the 10 relative forest maturity classes each have varying levels of error; the major forest types are only generalized models of forest ecosystem diversity in conterminous USA; and they encompass a range of natural variability in tree growth rates due to local physical environmental conditions that means in some locations there can be a mismatch between stand development and forest structure.

Discretion should be taken when interpreting the mature forest water overlay given the differing spatial scale of input datasets. The relative importance to surface drinking water dataset is provided at the scale of subwatersheds, which vary in size and shape as their bounds are largely determined by topographic and hydrologic features of the landscape (USGS USDA NRCS 2013). So, while we presented the water importance overlay at 30-m resolution, the masked values are from the coarser dataset, meaning there may be some fine-scale variation missed. There may also be some correlation between mature forest area and areas highly valuable for surface drinking water, as the layer incorporates forest metrics including forest cover, forest ownership and insect and disease risk (Mack et al. 2022). Given that the index incorporates many other non-forest variables, the impact of this correlation is likely minimal.

Finally, our approach to mapping mature forests does not include more commonly used classifications related to the dbh and age of dominant trees within a stand. Such an effort could involve cross-walking our spatial datasets with on-the-ground forest plot metrics derived from the Forest Inventory and Analysis (FIA) dataset.

5.0 Conservation Recommendations

President Biden's Executive Order (White House 2022) for forests aims to "institutionalize climate-smart management and conservation strategies that address threats to mature and old-growth forests on Federal lands." Mature forests, which include the old-growth forest class, provide important opportunities to conserve forests as natural climate solutions (Griscom et al. 2017, Moomaw et al. 2019) to meet both White House (2021, 2022) executive orders. However, the current status quo management of mature forests and low protection levels on federal lands presents unacceptable risks at a time when the global community is seeking ways to reduce the rapidly accelerating biodiversity and climate crises (Ripple et al. 2021). Thus, while our analysis presented three target scenarios of 30, 50, and 100 percent protections, there are climate, biodiversity, and drinking water justifications for choosing the upper bound 100% target for mature forests on federal lands with additional measures on non-federal lands to retain mature forests. Notably, the IRA component of mature forests includes remaining relatively intact forest blocks that would benefit from elevating the GAP status of IRAs through enhanced protective measures. Further, mature forests on BLM lands could be candidates for inclusion in the National Landscape Conservation System where they could receive GAP2 status. We note that the White House (2022) also calls for prioritizing the restoration of old-growth forests as "climate-smart forest stewardship." In our view, this can include allowing mature forests to develop into old growth over time as in the Eastern region and by passively restoring the national and regional deficits. It can also mean restoring the beneficial role of wildfires in maintaining diverse understories in fire-adpated older forests such as many dry mixed conifer, oak-hickory, and open pine systems. Typically, mature and old-growth forests that have experienced severe disturbance are logged soon after a natural disturbance event, including within administrative reserves (such as late-successional reserves under the Northwest Forest Plan in the Pacific Northwest) and even within IRAs. However, we recommend protections extend through post-disturbance stages to allow forests to recover carbon stocks (proforestation, Moomaw et al.

2019) and because most carbon in severe disturbances simply transfers from live to dead pools and soils (Law et al. 2021).

A large-scale effort to protect mature forests nationwide, including the primary and old growth forests within the highest end of the mature forest spectrum, would help the USA meet a range of multilateral commitments and objectives related to protecting and restoring ecosystem integrity. Ecosystem integrity has long been a bedrock principle in the United Nations, recognized in both the Rio Declaration and Agenda 21, where were agreed in 1992 at the United Nations Conference on Environment and Development (UNCED) (the 'Earth Summit'). The UNFCCC's Paris Agreement (UNFCCC 1/CP.21), agreed in 2015, carried forward the concept of ecosystem integrity in its preamble, and more recently the Intergovernmental Panel on Climate Change's 6th Assessment Report made numerous references to the fundamental importance of primary forests, ecological restoration and ecosystem integrity (IPCC 2022). Similarly, the Convention on Biological Diversity also recognizes the importance of primary forests and ecosystem integrity via decisions 14/5 and 14/30 agreed in 2018 at its 14th Conference of the Parties. The United Nations Strategic Plan for Forests 2030 (ECOSOC Resolution 2017/4), which builds on the 2007 UN Forest Instrument (A/RES/62/98 and A/RES/70/199), emphasizes ending deforestation and preventing forest degradation as key globally priorities. The United Nations global decade on restoration was launched in 2021, following on the 2011 Bonn Challenge, with a target of 350 million ha of restoration, including a pledge of 15 million ha from the United States. The UN Sustainable Development Goals also has a goal of halting and reversing land degradation (United Nations 2022). Mature and old-growth forest inventories (White House 2022) provide the foundation for much need policies that include the upper bound protection targets for these foress, which would allow the USA to fullfill its international obligations as a leader in the global effort to end forest degradation and deforestation.

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Figure Legends and Tables

Figure 1. Distribution of modelled mature forests for the conterminous USA. Important forested regions are numbered.

Figure 2. Regional zoom-ins of mature forest of the conterminous USA. Panels show Pacific Northwest (1), Pacific Southwest (2), Rockies (3), Southwest (4), Great Lakes (5), Southcentral (6), Northeast (7), and Southeast (8).

Figure 3. Indictive photographs of mature forests for some major forest types. (A) Mixed-conifer forest, Sequoia National Park, CA (B. Bryant). (B) Mature Eastern Hemlock (*Tsuga canadensis*) stand, Huron Mountain Club Upper Peninsula, MI (B. Boucher). (C) Bottomland hardwood forest, Congaree National Park, SC (J. Maloff, Old Growth Network). (D) North-Central Interior Dry-Mesic Oak Forest and Woodland (B.S. Slaughter). (E) Hardwood hammock forest, Starkey Park, FL (D. DellaSala). (F) Top ten largest bald cypress (*Taxodium distichum*) in Florida, Upper Pithlachascotee River Preserve (D. DellaSala). Note: nearly all old growth cypress was logged in the 1930s.

Figure 4. Distribution of mature forests within the proposed five state protection area (OR, WA, ID, MT, WY) including the Northern Rockies Ecosystem Protection Act (Bader 2000) by GAP classifications. GAP2.5 refers to inventoried roadless areas that are not fully protected.

Figure 5. Current Distribution of 182 forest and woodland ecosystem type categories under the IUCN Red List of Ecosystems (Comer et al. 2022). Nearly all these distributions include mature forests (Table S2).

Table 1. Mature forests area (%) within the proposed five state protection area (OR, WA, ID, MT, WY) that includes Northern Rockies Ecosystem Protection Act by GAP status. Outside GAP are areas with no GAP status, mostly on private lands.

GAP status	Area (ha)	Area (%)
GAP 1	1 174 117	15.4
GAP 2	342 516	4.5
GAP 2.5	2 331 074	30.7
GAP 3	5 033 750	66.2
GAP 4	295 733	3.9
Outside of GAP	755 909	9.9
Total area of mature forest	7 602 025	100
Total project area	79 173 694	-

Table 2. Area (x 1000 hectares) and percent (%) of mature forest within each FIA forest type group. GAP2.5 refers to Inventoried Roadless Areas (IRAs). IRAs outside national forests are classification errors in the database. Outside GAP are areas with no GAP status, mostly on private lands. Percentages are calculated by the total of each forest type group (rows).

Forest type group	GAP 1	GAP 2	GAP 2.5	GAP 3	GAP 4	Outside of GAP	Total
Alder/Maple	1.1 (0.7)	5.9 (3.5)	0.8 (0.5)	46.3 (27.6)	7.9 (4.7)	106.4 (63.5)	167.6
Aspen/Birch	84.8 (2.5)	629.5 (18.9)	288.3 (8.7)	864.5 (26)	221.3 (6.6)	1 528.8 (45.9)	3 328.9
California Mixed Conifer	185.7 (13.8)	58.4 (4.3)	139.9 (10.4)	783.9 (58.3)	10.7 (0.8)	304.9 (22.7)	1 343.6
Douglas-fir	654.3 (11.1)	217.6 (3.7)	1 112.9 (18.9)	3 946.9 (67)	235.1 (4)	840 (14.3)	5 893.9
Elm/Ash/Cottonwood	11.7 (1.2)	139.9 (13.8)	1 (0.1)	46.1 (4.6)	75 (7.4)	738.9 (73)	1 011.6
Fir/Spruce/Mountain Hemlock	1 308.2 (29.6)	154.8 (3.5)	1 298.5 (29.4)	2 688.9 (60.8)	86.3 (2)	182.2 (4.1)	4 420.4
Hemlock/Sitka Spruce	127 (26.2)	15.8 (3.3)	55.3 (11.4)	287.6 (59.4)	12.5 (2.6)	41 (8.5)	483.9
Loblolly/Shortleaf Pine	41.5 (0.6)	555.8 (8.1)	9.7 (0.1)	562 (8.2)	229.3 (3.3)	5489 (79.8)	6 877.6
Lodgepole Pine	413.5 (22)	101.4 (5.4)	681.8 (36.3)	1 258.7 (67)	38.3 (2)	67.9 (3.6)	1 879.8

Longleaf/Slash Pine	19.3 (1)	90 (4.8)	3.2 (0.2)	308.7 (16.6)	72.7 (3.9)	1 365.5 (73.6)	1 856.2
Maple/Beech/Birch	65.6 (1.3)	868.6 (16.6)	29.2 (0.6)	523.7 (10)	302 (5.8)	3 484.3 (66.4)	5 244.2
Oak/Gum/Cypress	126.9 (4.1)	398.6 (13)	1.5 (0)	303.1 (9.9)	108.2 (3.5)	2138.7 (69.5)	3 075.5
Oak/Hickory	280.8 (1.6)	1173.9 (6.9)	153.2 (0.9)	1 810.3 (10.6)	1 363.4 (8)	12 421.7 (72.9)	17 050.1
Oak/Pine	23.1 (1.1)	147.6 (7)	7.1 (0.3)	167.6 (7.9)	66.3 (3.1)	1 711 (80.9)	2 115.6
Other Western Hardwoods	28.1 (23.4)	5.2 (4.4)	31.7 (26.4)	61.8 (51.5)	5.5 (4.6)	19.5 (16.2)	120.1
Other Western Softwood	86.9 (35.2)	15 (6.1)	102.1 (41.3)	119.3 (48.3)	16.7 (6.8)	9.1 (3.7)	247
Pinyon/Juniper	405.5 (10.5)	346 (9)	483.6 (12.5)	2 076.4 (53.7)	552.4 (14.3)	485.3 (12.6)	3 865.6
Ponderosa Pine	135.1 (4.2)	103 (3.2)	174.2 (5.4)	1817.3 (56.7)	412.6 (12.9)	738.2 (23)	3 206.2
Redwood	7.2 (9.4)	8.3 (10.9)	0.1 (0.1)	7 (9.2)	11.7 (15.3)	42.1 (55.2)	76.3
Spruce/Fir	31.4 (2)	312.7 (20.1)	16.9 (1.1)	264.5 (17)	153.6 (9.9)	790.9 (50.9)	1 553.1
Tanoak/Laurel	12 (5.9)	17.2 (8.4)	5.7 (2.8)	46.5 (22.6)	23.1 (11.2)	106.6 (51.9)	205.4
Tropical Hardwoods	1 (5)	4.7 (22.3)	0 (0)	7.4 (35.4)	0.3 (1.5)	7.5 (35.9)	20.9
Total	4 212.6	5 632.4	4 751	18 610.1	4 125.5	33 425.3	67 183

Table 3. Total area of mature forests (x 1000 ha) and percent (parenthesis) for the conterminous USA by GAP and ownership. Percentages are calculated across rows. GAP2.5 refers to Inventoried Roadless Areas. IRAs outside national forests are classification errors of input datasets.

Ownership and tenure	GAP 1	GAP 2	GAP 2.5	GAP 3	GAP 4	Total per[Ψ] owner
National Parks	822.3 (96.1)	24.5 (2.9)	0.7 (0.1)	3.3 (0.4)	4.4 (0.5)	855.6 (100)
National Forests	2 995.1 (13.7)	2 322.5 (10.6)	4 775.1 (21.9)	14 120.5 (64.7)	137.2 (0.6)	21 834.3 (100)
BLM	161.1 (7.1)	394.5 (17.4)	29.9 (1.3)	1 706.9 (75.4)	0.1 (0)	2262.6 (100)
State	11 5 (2.2)	2 086.3 (39)	4.9 (0.1)	2 054.9 (38.5)	430 (8)	5 343.7 (100)

Federal	4 014.9	2 906.7	4 756.2	15 731.6	402.4	23 514.5
	(17.1)	(12.4)	(20.2)	(66.9)	(1.7)	(100)
Corporate private	13.5	215.4	3	232.4	645.2	11 223.5
	(0.1)	(1.9)	(0)	(2.1)	(5.7)	(100)
Family private	32.5	296	5.2	350	1 067.7	22 467
	(0.1)	(1.3)	(0)	(1.6)	(4.8)	(100)
Tribal	0.4	13.2	0.2	7.6	1 481.2	1 566
	(0)	(0.8)	(0)	(0.5)	(94.6)	(100)
Total per GAP	4 239	5 686.8	4 784.2	18 736.3	4 198.1	67 183
	(6.3)	(8.5)	(7.1)	(27.9)	(6.2)	(100)

[Ψ]Percentages do not always sum to 100% due to minor mapping errors from using different datasources.

Table 4. Total-above ground living biomass within mature forests (x 1M tonnes) by GAP and ownership. Percentages (in brackets) are calculated across rows. GAP2.5 refers to Inventoried Roadless Areas. IRAs outside national forests are classification errors of input datasets.

Ownership and tenure	GAP 1	GAP 2	GAP 2.5	GAP 3	GAP 4	Total per owner
National Parks	281	10	0	1	3	296
	(94.9)	(3.4)	(0)	(0.3)	(1)	(100)
National Forests	933	425	1 203	4 095	26	5 956
	(15.7)	(7.1)	(20.2)	(68.8)	(0.4)	(100)
BLM	31	64	7	484	0	580
	(5.3)	(11)	(1.2)	(83.4)	(0)	(100)
State	17	295	1	397	74	883
	(1.9)	(33.4)	(0.1)	(45)	(8.4)	(100)
Federal	1 241	509	1203	4 539	60	6 441
	(19.3)	(7.9)	(18.7)	(70.5)	(0.9)	(100)
Corporate private	3	35	0	42	89	1 970
	(0.2)	(1.8)	(0)	(2.1)	(4.5)	(100)
Family private	6	47	0	56	123	3 325
	(0.2)	(1.4)	(0)	(1.7)	(3.7)	(100)
Tribal	0	3	0	1	254	272
	(0)	(1.1)	(0)	(0.4)	(93.4)	(100)
Total per GAP	1 285	920	1 203	5 091	626	13 351
	(9.6)	(6.9)	(9)	(38.1)	(4.7)	(100)

Table 5. Area of land (x 1000 ha) and percentage area (parentheses) for each of the identified RLE risk status by GAP and landowner. Percentages are calculated across rows. GAP2.5 refers to Inventoried Roadless Areas. IRAs outside national forests are classification errors of input datasets.

	Not Evaluated	Data Deficient	Least Concern	Near Threatened	Vulnerable	Endangered	Critically Endangered	Total by GAP
GAP status								
GAP 1	1.9 (0)	28.4 (0.5)	3 129.2 (60.3)	1 220.9 (23.5)	623 (12)	181.9 (3.5)	5.1 (0.1)	5 190.4 (100)
GAP 2	1.8 (0)	74.5 (1.5)	1 685.4 (35)	616.6 (12.8)	1 340.4 (27.9)	1 026.4 (21.3)	67.3 (1.4)	4 812.4 (100)
GAP 2.5	0 (0)	0.4 (0.1)	247.1 (81)	46.5 (15.2)	11.2 (3.7)	0 (0)	0 (0)	305.2 (100)
GAP 3	10.4 (0)	139 (0.6)	9 198.4 (42.9)	6 875.9 (32.1)	3 874.3 (18.1)	1 268.1 (5.9)	86.3 (0.4)	21 452.3 (100)
GAP 4	1.4 (0)	76.6 (1.8)	1 040.5 (24.2)	550.5 (12.8)	2 073.2 (48.3)	538.9 (12.5)	13.3 (0.3)	4 294.4 (100)
Landowner								
National Parks	1.5 (0.2)	8.3 (0.8)	558.4 (57.1)	195.2 (19.9)	200.1 (20.4)	15 (1.5)	0 (0)	978.6 (100)
National Forests	12 (0)	93.9 (0.4)	11 963.5 (46.6)	7 327.5 (28.5)	4 359.2 (17)	1 762.5 (6.9)	175.5 (0.7)	25 694 (100)
BLM	0 (0)	5.8 (0.2)	520.3 (19.9)	1 456.9 (55.7)	631.9 (24.1)	2.1 (0.1)	0 (0)	2 617.1 (100)
State	2.8 (0.1)	105.7 (2.6)	1 390.2 (34.4)	326 (8.1)	1 252.2 (30.9)	948.8 (23.5)	20.1 (0.5)	4 045.9 (100)
Federal	11.3 (0)	115 (0.4)	12 454.2 (45.1)	8 369 (30.3)	4 869.4 (17.6)	1 677.8 (6.1)	148.4 (0.5)	27 645.1 (100)
Corporate private	3.6 (0)	419.8 (5.3)	1 618 (20.3)	969.3 (12.1)	2 651.3 (33.2)	2 111.4 (26.4)	213.9 (2.7)	7 987.4 (100)
Family private	15 (0.1)	450.8 (2.7)	2 701.1 (16)	827.7 (4.9)	7 176.4 (42.5)	5 493.9 (32.5)	224.1 (1.3)	16 889 (100)
Tribal	0 (0)	16.4 (1)	738.3 (43.9)	447.1 (26.6)	457.4 (27.2)	21.2 (1.3)	0.2 (0)	1 680.6 (100)
Total by risk status	34.5 (0.1)	1 152.9 (1.9)	19 513.9 (32.4)	11 055 (18.4)	17 009.3 (28.3)	10 762.5 (17.9)	630 (1)	67 183 (100)

Table 6. Mature forest area (ha) in each Relative Importance to Surface Drinking Water Class by GAP status and Land Tenure, with the percentage of total mature forest in the respective GAP/Tenure in parentheses.

	Class 1 (0-25%)	Class 2 (26-50%)	Class 3 (51-75%)	Class 4 (76-100%)	Total
GAP Status					
GAP 1	1,188,095 (28.2)	1,021,604 (24.2)	1,218,859 (28.9)	790,612 (18.7)	4,219,170 (100)
GAP 2	1,804,722 (31.8)	915,163 (16.1)	1,541,173 (27.2)	1,411,752 (24.9)	5,672,810 (100)
GAP 2.5	1,646,869 (34.4)	1,220,674 (25.5)	1,355,166 (28.3)	561,520 (11.7)	4,784,229 (100)
GAP 3	5,922,561 (31.6)	4,494,644 (24)	4,720,470 (25.2)	3,598,512 (19.2)	18,736,188 (100)
GAP 4	1,178,791 (28.1)	773,969 (18.4)	1,370,386 (32.7)	873,587 (20.8)	4,196,733 (100)

Outside GAP	6,077,230 (20.6)	3,883,699 (13.2)	7,433,106 (25.2)	12,130,797 (41.1)	29,524,833 (100)
Land Tenure					
National Forests	5,713,619 (26.2)	5,498,207 (25.2)	6,119,473 (28)	4,501,227 (20.6)	21,832,525 (100)
National Parks	257,648 (30.1)	145,354 (17)	214,784 (25.1)	237,857 (27.8)	855,644 (100)
Federal Land	7,144,748 (30.4)	5,709,127 (24.3)	6,217,105 (26.5)	4,421,747 (18.8)	23,492,727 (100)
State Lands	1,704,860 (32.0)	803,361 (15.1)	1,360,235 (25.5)	1,463,130 (27.4)	5,331,587 (100)
Family Private Lands	4,381,601 (19.5)	3,208,018 (14.3)	6,200,135 (27.6)	8,666,291 (38.6)	22,456,045 (100)
Corporate Private Lands	3,081,796 (27.5)	1,815,543 (16.2)	2,672,084 (23.8)	3,653,002 (32.6)	11,222,425 (100)
Tribal Lands	611,203 (39)	384,502 (24.6)	517,106 (33)	53,000 (3.4)	1,565,810 (100)
BLM Lands	1,245,174 (55.6)	415,190 (18.5)	358,263 (16)	220,752 (9.9)	2,239,379 (100)
Total	17,818,269	12,309,753	17,639,160	19,366,781	67,133,962