Chapter 1

Key Findings of the 2020 RPA Assessment

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The 2020 Resources Planning Act (RPA) Assessment explores the present condition and 50-year outlook for the Nation's forest and rangeland resources. This chapter follows the organization of the resource-specific chapters (Chapters 4 through 11). Each section provides the key findings of the corresponding chapter, as well as the results that support those findings. Key findings apply to the conterminous United States unless otherwise specified.

Land Resources

Developed lands continue to encroach on natural ecosystems and agricultural areas, with about half of new developed lands converting from forest or rangeland.

In all RPA regions, the developed land area generally exhibited the largest net gains of all land uses from 1982 to 2012. As a result, development was a primary driver of net changes in most nondeveloped land uses. About half of new developed lands converted from forest or rangeland, while most of the remainder converted from agriculture (crop and pasture) land uses. The rate of transition to developed land use from other land uses increased from 1982 until 1997. Although the area of developed land continued to increase after 1997, the rate of transition began to decrease.

Developed lands are projected to continue to expand in all scenarios, although less than projected in the 2010 RPA Assessment. The expansion of developed lands varies across regions and is projected to be larger under high socioeconomic growth scenarios and smaller under hotter climate futures.

The RPA land use change models describe future dynamics of privately-owned land, where the choices between forest, rangeland, agriculture, and developed land uses are driven principally by the relative economic returns to those land uses. A continued increase of developed land area is projected under all RPA scenario-climate futures, but more so for RPA scenarios with higher levels of population and income growth and less so under hotter climate futures. The increase in developed lands is projected to occur at slower rates than previously projected in the 2010 RPA Assessment. Prior projections were based on data from 1982 to 1997, when rates of new development were increasing, while the 2020 RPA land use change models used data from 2000 to 2012, when rates were decreasing from the peak (or highest rate) in 1997. The decline in the rate of development results in smaller projected conversions from nondeveloped to developed land.

The regional differences in projected increases of developed land area are generally larger than within-region differences attributable to RPA scenarios. The largest projected increases in developed land area appear in the RPA South Region and smallest in the Pacific Coast and Rocky Mountain Regions.

Forest land area increased slightly over the past decades, mostly at the expense of pasture and crop land areas. This trend is expected to shift to decreasing forest area under all scenarios, although at lower rates than projected by the 2010 Assessment.

Net gains from other land uses, principally crop and pasture land, offset forest losses to developed land from 1982 to 2012, resulting in a slight net increase in forest land area. Non-Federal forest land area increased slightly in the North and South Regions, stayed stable in the Rocky Mountain Region, and decreased slightly in the Pacific Coast Region. Privately owned forest land area is projected to decline in the future, although the projected 50-year net loss is 35 to 55 percent lower than was projected in the 2010 Assessment. While 91 percent of current privately owned forest land is projected to remain in forest use in 2070, most of the loss is projected to convert to developed land. The projected decreases in forest land area are largest in the South Region and relatively small in all other regions.

Forest cover fragmentation slowed over the past decade but continues overall and is expected to continue into the future for the western and southeastern subregions, while decreasing slightly in the north and central subregions.

Forest land cover fragmentation increased in all RPA regions from 2001 to 2016, although at a decreasing rate after 2006. A net loss of 2.6 percent of forest cover from 2001 to 2016 resulted in an overall net loss of 6.4 percent of the "interior" forest cover, with regional losses of interior forest ranging from 2.7 percent in the South Region to 12.3 percent in the Rocky Mountain Region. The analysis indicated stabilization or recovery of interior forest in the North and South Regions after 2006.

Projections hold that interior forest area will decrease under most RPA scenario-climate futures, except for projected increases under a "hot" climate future. The projected national decreases are relatively small across scenario-climate futures, especially when compared to regional changes. Four RPA subregions are projected to gain interior area (Northeast, North Central, South Central, and Great Plains Subregions) while four others are projected to lose interior area (Pacific Southwest, Pacific Northwest, Intermountain, and Southeast Subregions).

Changes in unfragmented forest land cover are more dynamic in private forests of the South, while changes in the West are slower and concentrated in public lands.

The overall dynamics (i.e., gain and loss) of "core" forest cover (unfragmented forest cover in the vicinity of forest land use) from 2001 to 2016 were greatest on privately owned land in the South Region, likely reflecting the relatively larger areas of harvest and subsequent forest regeneration in that region. In contrast, most of the net change (primarily net loss) of core forest cover occurred on public land in the Pacific Coast and Rocky Mountain Regions

Most forest lands remain in "natural" landscapes, but an increasing proportion is expected to be in "interface" landscapes near developed or agriculture use in the future.

Forest tends to be the dominant land cover where it occurs; however, developed or agriculture land cover near forest poses ecological risks. In both 2001 and 2016, 88 percent of forest cover area was in landscapes dominated by natural land covers (forest, grass, shrub, water, wetland, or barren cover occurring in at least 60 percent of the neighborhood area), while 31 percent was in "interface" landscapes containing at least 10 percent of developed or agriculture land cover.

Considering all land area (not just forest land), the period 2001 to 2016 saw a net decrease in natural-dominated and noninterface area in all RPA regions, alongside a net increase in developed-dominated and developed interface area. Agriculture-dominated and agriculture interface area decreased in all regions except the Rocky Mountain Region. Projections suggest a continuation of those regional trends under all RPA scenario-climate futures, except for a reversal of agriculture trends in the Rocky Mountain Region. This leads to a decrease in natural-dominated and agriculture-natural interface lands, alongside an increase in developed-natural interface lands.

Economic and regional factors tend to be more important drivers of land use area changes than changes in climatic conditions.

Land use projection models stemming from integrated scenarios of socioeconomic and climatic change indicate that socioeconomic factors tend to be more important drivers of future land use area change than do changes in climatic conditions. Similarly, the future patterns of land use change are driven more by the socioeconomic components of the RPA scenario than by projected climatic factors, except in less-modified landscapes where both drivers had about the same degree of impact. In the economic land value models underlying the land use projections, the financial returns to developed and agricultural land uses often far exceed the return to alternative land uses. Therefore, when land development returns are projected to be high, as in the high-growth RPA scenario, conversion to developed land is accelerated regardless of the climate impact. However, this accelerated effect is dampened as temperatures rise in the future.

Disturbances to Forests and Rangelands

The annual area of fire in forests and rangelands has increased since 1984. The average annual area burned between 2000 and 2017 was more than double the pre-2000 average.

Fire is essential in many forest and rangeland ecosystems, but changes in fire regimes can threaten those ecosystems. In forests, large fires burned 0.13 percent of the total forest area on average annually between 1984 and 2000, increasing to 0.37 percent annually between 2000 and 2017 (a 189-percent increase). In rangelands, the total area burned per year averaged 0.45 percent of the total area since 2000, representing an increase of 119 percent over the pre-2000 average of 0.19 percent per year. Increasing fire area trends occurred for forests and rangelands in all RPA regions except for the North Region, where fire is relatively rare. These increases in area burned have posed challenges for management and can impact the ability of forests and rangelands to provide clean water, carbon sequestration, and other ecosystem goods and services.

The two western RPA regions have generally had higher exposure to fire and drought than the eastern regions, as well as the greatest rates of tree mortality caused by insects and diseases. In contrast, forests in the RPA South Region have experienced the highest rates of harvest removals.

Forest and rangeland ecosystems experience a variety of disturbances that differ across regions. On average, larger forest and rangeland areas burned annually in the RPA Pacific Coast and Rocky Mountain Regions than in the eastern regions from 2000 to 2017. The highest annual burned area averages occurred in the Rocky Mountain Region, with 403,000 ha of forests and 638,000 ha of rangelands burning per year. In the Pacific Coast Region an average of 259,000 ha of forests and 218,000 ha of rangelands burned per year. Forests in those two regions also had the greatest areas of moderate- and high-severity fires. Forests and rangelands in the Pacific Coast Region and rangelands in the Rocky Mountain Region were exceptionally dry during the mid-2010s. A major drought also occurred in Texas and other parts of the South Region from 2011 to 2012, impacting both forests and rangelands. Summaries of forest canopy mortality from insect and disease agents show generally higher rates in the two western RPA regions than in the eastern regions. While the RPA South Region generally had lower rates of fire, drought, and insect and disease agents, it had the highest annual area of forest harvesting, accounting for more than 65 percent of all removals in the United States each year from 1986 to 2010. Consideration of these regional differences in disturbances can help direct management and policy efforts aimed at helping forests adapt to changing conditions.

The highest rates of invasion by nonnative plants occur near agricultural and developed land uses, primarily in forests in the RPA South Region and portions of the North Region, and rangelands in the Pacific Coast Region.

Invasion of forest and rangeland ecosystems by nonnative plants can cause ecological and economic impacts. Forests in the RPA South Region had the highest rate of invasion (58 percent), based on data collected from 2005 to 2018, followed by the North Region (55 percent). Forests in the two western regions were considerably less invaded (8 percent in the Rocky Mountain Region and 5 percent in the Pacific Coast Region). Within the two eastern regions, forests in counties in the southeastern, mid-Atlantic, and Midwestern States were most likely to be invaded by nonnative plants. Those counties tend to contain agricultural or developed land uses or are located near major metropolitan areas. Invasion rates of rangelands by nonnative plants were highest in the Pacific Coast Region, peaking in coastal California where several counties near San Francisco and Los Angeles host more than 300 nonnative plant species. Collection of consistent data on invasion by nonnative plants has only recently begun in both forests and rangelands across the United States, resulting in sparse data in some locations. As more data are added, additional regional and national patterns may emerge, thus providing better information to prioritize management of invasive species.

Fire-caused tree mortality in forests is expected to increase by 2070. The highest rates of fire mortality are expected if climate follows the hot or dry climate futures under any of the high warming RPA scenarios.

The annual volume of forest trees killed by fire is expected to increase over time across the United States and in each RPA region under all RPA scenario-climate futures. Annual fire mortality volume is projected to increase nationally between 55 and 108 percent from 2020 to 2070. In forests of the RPA Rocky Mountain and Pacific Coast Regions, where fire activity is highest, fire mortality volume is projected to increase between 20 and 55 percent (Rocky Mountain Region) and between 63 and 100 percent (Pacific Coast Region). In addition to increases in fire mortality volume, increases in the annual area of moderate-severity fires are expected in all RPA regions by 2070 under all RPA scenarios. In the Pacific Coast and South Regions, the area of high-severity fires is also expected to increase. In the Rocky Mountain and North Regions, projections indicate that increase or decrease in the area of high-severity fires depends on the RPA scenario-climate future. The greatest increases in fire mortality volume and in areas of moderate- and high-severity fires by 2070 were generally projected by the RPA dry or hot climate model projections under a high warming future (RPA scenarios HL, HM, and HH). The smallest increases were projected by the least warm climate model projection, regardless of the RPA scenario.

Drought exposure for forests and rangelands is expected to increase by 2070, and forest and rangeland ecosystems in the Southwest are expected to experience the most substantial increases.

The amount of forest land and rangeland experiencing drought is projected to increase under all RPA climate futures. More than 50 percent of the Nation's forests and rangelands are projected to be exposed to moderate, severe, or extreme drought in most years during mid-century (2041 to 2070) by the dry and hot climate projections under a future with high atmospheric warming. Under this same warming future, the middle climate projection also identifies greater than 50-percent exposure to drought for both forests and rangelands in many years during that period. Wetter conditions and lower levels of atmospheric warming result in lower percentages of forest area exposed to drought. Many forest and rangeland ecosystems in the Southwest could see large increases in drought exposure by mid-century, compared to recent levels of exposure (1989 to 2018). These ecosystems include the pinyon/juniper woodlands forest type group and the grassland and creosotebush desert scrub rangeland vegetation types.

Forest Resources

Important forest types are expected to lose area due to forest loss, conversion to planted pine following harvest, climate, and succession. These forest types include aspen/birch in the RPA North Region, oak/gum/cypress in the South, Ponderosa pine in the Rocky Mountains, and hemlock/Sitka spruce in the Pacific Coast Region.

Forests provide many goods and services. Some of these goods and services are specific to individual forest types, and knowledge of how those types are projected to change is therefore important. Most forest community types are expected to lose area between 2020 and 2070 due to a combination of conversion to other land uses, harvest and planting to a different species, climate effects, and succession to other forest community types. The extent of major forest types in the eastern RPA regions are projected to change more than the forest types in the western RPA regions. The projected areas of commercially important forest types such as loblolly/shortleaf and Douglas-fir vary more in response to different RPA scenarios than to different climate projections, while other types such as longleaf/slash pine and maple/beech/birch are more sensitive to the climate projection. Compared to other forest types, aspen/birch forests are projected to lose the most area by 2070. Oak/gum/cypress forests are also projected to decline in area, with a substantial portion lost to loblolly/shortleaf forests. Loblolly/shortleaf forests are among the few forest community types projected to increase in area by 2070.

Timberland growing stock volume is projected to increase through 2050. Post-2050, growing stock volume trajectories depend on roundwood demand and land use choices.

Future forest volume is influenced by shifts in productivity, land use choices, management actions and objectives, and markets. Timberland growing stock volume is projected to increase until 2050. After 2050, the projected trajectories of growing stock volumes vary across RPA scenarios. Under RPA scenarios with lower demand for roundwood and less forest loss, growing stock volume is projected to continue to increase through 2070. Under RPA scenarios with higher roundwood demand and increased forest loss, volume is projected to decrease from 2050 to 2070 but remain larger than in 2020. While scenarios with higher roundwood demand suggest futures with reduced volume, the 39- to 46-percent increases in harvesting for products in those scenarios support an expanding forest products sector. The future growing stock volume trajectories and their sensitivity to roundwood demand and land use change differ regionally, pointing to regional variability in both projected forest trends and the pressures driving those trends.

Aboveground biomass carbon density (carbon per unit area) is projected to increase by 17 to 25 percent over 2020 densities by 2070, while annual carbon stock change is projected to decrease, indicating carbon saturation of U.S. forests. The forest ecosystem is projected to become a net source of CO_2 by 2070 under futures that include high roundwood demand and net forest loss.

Forests provide a suite of ecosystem services, including the storage and sequestration of carbon. The density of aboveground biomass carbon is projected to be between 66.8 Mg ha^{-1} and 71.7 Mg ha^{-1} in 2070, representing an increase over the average density value in 2020, and an even larger increase over the 1990 value. Specifically, the average hectare of forest in 2070 is projected to have 17 to 25 percent more carbon stored in aboveground biomass than the average forest hectare had in 2020, and 51 to 62 percent more than 1990. The pool of carbon in aboveground biomass is projected to continue to increase over the projection period, although at a decreasing rate due to conversion of forests to other land uses, forest disturbances, and aging. These results suggest that the forest ecosystem carbon sink will saturate in the future, with total aboveground carbon stocks leveling off by 2070. Forests may become a net CO_2 source by 2070 depending on forest conversion and roundwood demand.

Projections suggest that harvested wood carbon annual stock change rates in 2070 will be greater than net forest ecosystem annual stock change rates under moderate- and high-growth future scenarios.

In 2019, forest sector carbon stock change was attributed to forest ecosystem carbon pools (73 percent), harvested wood carbon pools (14 percent), and land use conversions to forest (13 percent). Annual stock change rates across the forest sector are expected to decrease from 2030 to 2070, although the amount of carbon in the forest ecosystem is still projected to increase over this period. At the same time, an increase in wood products derived from U.S. roundwood is projected, particularly under moderate and high economic growth scenarios. The greater annual production of wood products in the United States in those scenarios leads to harvested wood carbon (harvested wood products in use and harvested wood stored in solid waste disposal sites) accumulating at an increasing annual rate. As a result, the carbon stock change rate in harvested wood carbon is expected to become larger than the forest ecosystem carbon stock change rate as early as 2060 under the moderate and high economic growth scenarios. This suggests that as forests mature and are increasingly affected by land use change and disturbance, the harvested wood carbon pools will become increasingly important for offsetting emissions from other sectors of the economy.

Although forest area increased 3.6 percent between 1977 and 2017, forest area is projected to decrease between 2020 and 2070, with net losses primarily driven by conversion to developed uses.

Total forest area of the conterminous United States in 2017 was 635.3 million acres, an increase of 3.6 percent from 612.4 million acres in 1977; however, forest area is projected to decrease across all RPA scenarios to between 619 and 627 million acres in 2070. Forest area projections generally vary more in response to different RPA scenarios than to different climate projections. The amount of future forest loss differs regionally: the South and Pacific Coast Regions are projected to lose the largest amounts of forest area. Loss of forest affects a range of ecosystem services. For example, between 194 and 517 million metric tons of carbon in the soil are expected to be transferred from forests to other land uses from 2020 to 2070 because of forest conversion.

There are an estimated 9.6 million family forest ownerships across the United States, and they control more forest land than any other ownership category (39 percent excluding interior Alaska).

Across the United States, an estimated 9.6 million family forest ownerships (i.e., individuals, families, trusts, estates, and family partnerships) guide and manage forests, with ownership patterns varying substantially among regions. Nationally, excluding interior Alaska, family forest ownerships control more forest land than any other ownership group. More than half of the forest land in the South and North Regions, 56 percent and 52 percent, respectively, is owned by millions of family forest owners. Most family forest owners have relatively small forest holdings (62 percent own less than 10 acres), but the majority of acres are in relatively larger forest holdings (58 percent of family forest acreage is in holdings of at least 100 acres). Focusing on family forest acreage for ownerships with 10+ acres of forest land, nearly half is owned by people who have commercially harvested trees, yet only a relatively small portion of family forest land is owned by people who have written management plans (23 percent) or recently received management advice (34 percent). Through outreach and education, the forestry community can help family forest owners meet their needs now and in the future.

Forest Products

The future of U.S. markets is shaped by strong growth in emerging economies, stable to slightly growing domestic demands, and by policy factors related to energy embedded in alternative scenarios. U.S. timber production and consumption are projected to remain strong, with varying levels of growth across RPA scenarios, but with important changes in the product mix.

Projections of roundwood production are expected to exceed pre-recession (2007 to 2009) levels by 2070. Growth in roundwood production is projected to exceed growth in domestic consumption across most scenarios, the difference adding to U.S. net exports. Higher economic growth domestically and internationally (RPA scenarios HH and LM) favors stronger export markets for product categories in which the United States currently is already a net exporter: softwood and hardwood roundwood, hardwood lumber, nongraphics paper (i.e., other paper and paperboard), and wood pellets. Under these same high economic growth scenarios, import-dependence on wood-based panels moderates, while import-dependence on softwood lumber deepens.

In all scenarios, U.S. newsprint production and consumption declines to historically low levels by 2070, while printing and writing paper also declines, but at a slower rate. Meanwhile, projections of other paper and paperboard are tied more closely to economic growth and rising overall demand for paper for packaging. Projected U.S. wood pellet production varies widely by scenario, depending on global policy and shifts in preferences as defined by the RPA scenarios.

U.S. industrial roundwood production is projected to rise faster than derived product manufacturing demand, resulting in the United States capturing a growing share of global industrial roundwood export markets.

Climate change is expected to increase timber growth rates, allowing timber inventories (stocks) to rise despite growing production of industrial roundwood. In addition, technology change enables manufacturers to produce more output per unit of wood input. These trends result in a market where industrial roundwood supply grows faster than demand in the United States, leading to rising exports of wood products to developing economies such as China and India. Industrial roundwood consumption in Asian markets is projected to exceed that of the North American market in most scenarios by mid-century.

The U.S. South is projected to remain the dominant timber producing region in the world, producing around 10 percent of total industrial roundwood under all RPA scenarios.

The inventory of standing timber in the South has rapidly accumulated since the recession (2007 to 2009), which

has led to a rising ability of timber producers to supply the market, especially softwood roundwood in the South. The South produced around 16 percent of global softwood industrial roundwood and around 6 percent of hardwood industrial roundwood in 2015. Even though demand for roundwood rises significantly in most scenarios through mid-century, due in large part to rapid economic development in China and India, the United States maintains its market share through 2070. Depending on future population and economic growth, the average global price of hardwood industrial roundwood is projected to rise by 19 to 219 percent and softwood by 3 to 127 percent between 2015 and 2070. In the United States, projections indicate price increases of 4 to 51 percent for hardwood and 12 to 82 percent for softwood.

The U.S. paper sector has undergone a transition related to declining demand for graphics paper and the shift in global markets to overseas paper production in the last 20 years that is projected to continue into the foreseeable future.

The U.S. production of newsprint has declined from a high of 6.7 million metric tons in 2000 to around 1 million metric tons in 2018. Newsprint production and consumption are projected to decline to historically low levels by 2070, along with the production and consumption of printing and writing paper, albeit at a slower rate. Although industrial capacity to produce these two categories of paper is projected to decline nationally as manufacturing facilities close along with declining demand, no such declines are anticipated for other uses of paper. In fact, growth in other paper and paperboard is projected to continue to rise through to 2070, offsetting the declines from newsprint and printing and writing paper. Consequently, U.S. total wood pulp production is projected to grow by 8 to 39 percent nationally between 2015 and 2070, depending on the scenario.

Overseas demand for hardwood roundwood and lumber provides a base of support for domestic U.S. production.

The U.S. housing industry has historically provided strong markets for softwood roundwood, but moving forward, markets for hardwood roundwood are less tied to the growth in residential housing. The size of the domestic market for the U.S. manufacture of wood furniture and other uses is projected to stagnate over the coming decades, implying greater relative importance of hardwood roundwood and lumber export markets. All scenarios project stable export markets for hardwood industrial roundwood and hardwood lumber.

Projected futures in the production and consumption of wood to generate energy depend on policy assumptions and consumer preferences and vary widely by RPA scenario.

Policy choices and consumer preferences related to the carbon benefits of wood energy can have strong implications for the future of the industry. Our RPA scenarios aim to capture a broad range in bioenergy demand consistent with the scenarios' assumptions about future socioeconomic conditions, and thus show the range in possible futures for the wood pellet market. Specifically, the market for wood pellets is projected to not grow significantly or even decline under lower and moderate-growth scenarios (RPA scenarios HL and HM), while high-growth conditions associated with RPA scenario HH and favorable policy conditions inherent in the moderate-growth scenario LM result in wood pellet production projections that more than double by 2070 to over 20 million metric tons.

If current policies encouraging wood use in energy production are maintained in Europe, the United States is projected to have a durable and growing wood pellet export market through 2070. Across all RPA scenarios, future pellet production does not exceed 4.2 percent of total wood production.

Although pellets represent a small fraction (less than 2 percent) of all roundwood consumed, wood pellets have grown rapidly, destined to the European Union (EU) in support of that region's renewable energy policies. Europe is the world's largest wood pellet producer and consumer, mainly owing to the EU's binding renewable energy targets for 2020 and 2030, and other environmental legislation. The gap between the supply and demand within the EU is contributing to the increasing importance of global wood pellet trade. Prospects for domestic production and export of wood pellets depend in large part on strong overseas markets, which are largely maintained currently by EU policies. Wood pellet manufacture would not rise to much more than 4.2 percent of all roundwood consumption by 2070 under RPA scenario LM and would remain less than 1 percent under scenario HL. Concerns about the sustainability and carbon implications of wood pellets as an energy source would therefore be most pronounced under the LM and least under the HL scenarios, but in both cases would not define substantial changes in overall production/carbon at the sector level.

Rangeland Resources

Rangeland health is relatively unchanged since the 2010 RPA Assessment. The greatest overall impacts to rangeland health have been observed in the Pacific Coast Region and in the southwestern part of the United States due to increases in invasive annual grasses and drought.

Relatively healthy rangeland conditions were found on approximately 75 percent of non-Federal rangeland from 2011 to 2015 and between 79 to 86 percent of rangelands managed by the U.S. Bureau of Land Management from 2011 to 2018. Despite the overall healthy conditions, recent data suggest that an increasing extent and magnitude of invasive annual grasses is reducing rangeland health.

Reductions in rangeland health are especially acute in the Pacific Coast Region, predominantly from invasive annual grasses, while the Southwestern United States has experienced reductions in rangeland health from reduced hydrologic function and biotic integrity, which seem to be linked to novel drought conditions. It is currently unclear whether these effects are transitory, but the impacts of invasive annual grasses are often irreversible and present numerous management challenges.

Rangeland production is increasing in northern parts of the rangeland extent and decreasing in the south, with corresponding changes in bare ground. Interannual variability in productivity is increasing in most areas at the same time, with the largest changes since 2000 having occurred in the Southwestern United States. Current production trends are projected to intensify in the future and become more variable on an interannual basis.

Productivity changes have led to minimal changes in overall national forage availability, but regional and local impacts have been significant. Annual production has been increasing across the northern extents of conterminous United States rangelands, especially the northern Great Plains and eastern Washington and Oregon. Increases in the annual production across the northern Great Plains have been primarily due to increased growing season precipitation since 1984 and the subsequent increase in rangeland woodiness, while increases in eastern Washington and Oregon were probably due to the increased cover and extent of invasive annual grasses, especially cheatgrass *(Bromus tectorum)*. In contrast, rangeland productivity has been decreasing across the southern extent of rangelands, most notably in the desert Southwest and southern California. Decreases in those areas are driven by the acute drought conditions that have been pervasive for years to decades. In addition to asymmetric changes in the amount of production across rangelands, interannual variation in production is also increasing, especially since 2000. The highest interannual variability in productivity occurs in the South and Pacific Coast Regions.

Projections suggest that many of the trends that have been observed since 1984—including decreased production in the South, increased production in the North, and greater interannual variability—will continue and possibly intensify in the future. The Southwest is projected to experience the largest and most widespread reductions in rangeland productivity, especially in desert areas, followed by the southern plains and Four Corners area. The northern Great Plains, especially North Dakota, South Dakota, and Montana, are projected to experience the largest gains in productivity.

Rangelands have been steadily converted to developed and agricultural land uses. Urbanization is projected to be responsible for most of the future reduction in rangeland extent, especially in the Pacific Coast Region.

Non-Federal rangelands occupied about 163 million ha in 2017, representing a loss of 6 million ha (3.6 percent) since 1982. Most losses were driven by net movement of 2.3 million ha to developed uses (urban and rural transportation infrastructure) followed by about 1.2 million ha to crop land. Hotspots of urban growth rates have been observed since 2010 in area dominated by rangelands such as those near Bozeman, MT; Boise, ID; and Phoenix, AZ. These hotspots of growth are projected to continue in the near future. While rangeland losses are expected to be minor nationally—decreasing just 2.7 percent by 2070—regional and local impacts are expected to be significant, especially when considering issues such as habitat connectivity and wildlife migration routes. The Pacific Coast Region is projected to lose the most rangeland area, about 6 percent of the current base, but some counties within that region may lose up to 25 percent of their rangelands to urbanization. Under a high atmospheric warming future, 61 counties are projected to exhibit losses exceeding 3 percent in the Pacific Coast Region.

Water Resources

Both per capita water use and total water use are declining in many parts of the country.

Water use is driven by changes in socioeconomic and climate variables, with the relative influence of drivers varying by sector. Household water use is driven largely by population, but also by policies and technologies aimed at water conservation. Increased use of high-efficiency appliances, low-flow toilets, and programs to limit outdoor turf have led to remarkable declines in water use in many communities, even in places with population growth—domestic water use decreased by 10 percent from 2005 to 2015 despite an 8-percent increase in population. Per capita household withdrawals fell from 98 gallons per day in 2005 to 82 gallons per day in 2015. During the same period, surface freshwater withdrawals decreased in 64 percent of counties in the conterminous United States to about 322 billion gallons per day. Irrigation withdrawals fell by 7 percent, and thermoelectric withdrawals fell by 34 percent. Some of those reductions in water use were necessary due to extreme droughts throughout the last two decades.

Despite reductions in water use, many regions increasingly experience water shortages due to extended dry periods.

From households to agriculture to industry, meaningful changes in human behavior and conservation practices have resulted in reductions of water use. Nevertheless, large regions of the United States face increasing water scarcity. Droughts are increasing in frequency and duration. Water shortage occurs when demands are partially or fully unmet, a condition also referred to as socioeconomic drought. Much of the United States experienced at least moderate water

shortages during the period of 1986 to 2015. The southern Great Plains and Rocky Mountain Subregions, southern California, and northern Florida already experience high-intensity shortages of less than a month in length, as well as relatively less intense shortages with duration equal to or greater than 6 consecutive months.

Projected changes in national consumptive water use range from a 9-percent decrease to a 235-percent increase, with the largest impacts resulting from the needs of agriculture in response to climate change.

Across RPA scenarios and climate projections, changes in domestic water use are projected to range from a 55-percent decrease to a 2-percent increase. Despite projected decreases in household water use, changes in total consumptive water use are projected to range from a 9-percent decrease to a 235-percent increase by 2070. In most places, increases or decreases in water use depend on agriculture's response to changes in precipitation and temperature. Nationally, agriculture accounts for 42 percent of total water withdrawals, so changes in agricultural water use have the largest impact on aggregate water use. Over the last few decades, irrigation practices have become more efficient. Across the Western United States, both acres irrigated and water applied per acre have fallen. In the East, however, irrigation has become more widespread to ensure more reliable farm yields. Future water use depends on whether trends in the East continue and how western farmers respond to drier conditions, particularly in the southern Great Plains, Intermountain, and Pacific Southwest Subregions, for which results across climate projections are highly varied.

Changes in projected aggregate water yield by mid-century range from a 25.7-percent increase under a wet future to a 10.9-percent decrease under a dry future.

Climate model projections for precipitation and water yield (which is strongly correlated with precipitation) are more varied than projections for temperature. The RPA projections associated with a dry future anticipate decreases in water yield in the South, Southeast, and Great Plains, whereas increases in water yield are projected in these same regions under wet and hot RPA futures. Water yield projections consistently increase for the much of the Western United States but decrease in the Southwest. Much warmer temperatures in the South are projected to increase potential evapotranspiration more than for any other region, amplifying the effects of decreased precipitation and leading to further declines in water yield.

Short-duration droughts are likely to turn into long-duration droughts, and the intensity of drought is likely to increase substantially. Under higher future atmospheric warming, droughts lasting more than a year are projected to occur four times more often and increase in intensity by 76 percent.

Droughts can be characterized by how often they occur and how long they last. Both short- and long-term droughts are projected to increase in intensity and duration in the southern Great Plains, and short-term droughts are projected to last longer in the middle Great Plains, Southwest, and South. Extreme droughts that may be relatively infrequent today are projected to become more frequent by mid-century, especially under a future with high atmospheric warming. Under this future, droughts that last longer than 3 years are projected to be more than 19 percent more severe on average (while shortages increase by 19 percent), and droughts lasting more than 10 years are projected to occur about 6 times more often.

Adaptation options like increased reservoir storage have limited ability to curtail shortage in the long term. Responses to climate change will probably require substantial transfers from agriculture to urban users, which could have serious negative impacts on rural communities.

As water scarcity increases and droughts become more frequent, economic pressure will likely shift water use between sectors and regions. Longer term responses to climate change might require transfers from agriculture to urban users, which could have serious negative impacts on rural communities. Past droughts, as well as increasing competition with municipal water uses, have led some farmers to rely more on groundwater than in the past. Aquifers throughout the country are being drawn down at rates that far exceed their recharge rates. Communities have also sought to increase their reservoir storage, which might provide short-term relief, but is often contentious and ultimately relies on sufficient water yield to fill the reservoirs, an increasing problem throughout the Nation. In areas that rely heavily on hydroelectric power, reservoir levels may become low enough to affect power generation.

Biodiversity: Wildlife and Aquatic Biota

Trends from breeding bird surveys indicate population declines in at least 20 percent of all bird species across habitat types since the 1950s/1960s, and in more than 50 percent of species that occupy grasslands or are ground nesting. These declines are linked to land use modifications of habitats as well as introduced species and loss of habitat connectivity.

Wild bird populations have long been considered good indicators of environmental threats like landscape change because changes in habitat affect the abundance and diversity of bird species that occupy a particular region. In addition, many bird species are highly migratory, making them vulnerable to changes in land use and climate at different stages of their lifecycle as they move among environments, some of which are outside the United States. Population

declines and variability over long- and short-term time periods reflect ongoing stress on existing avian fauna. Data from long-term breeding bird surveys show declines in population sizes. Grassland bird species had the greatest declines in long-term trends, with 54 percent of species showing significant decreases, while only 4 percent had significant increases. Several categories of harvested birds, including species of geese and ducks, have remained stable over the long-term, but webless migratory birds, including American woodcock and mourning dove, are in decline.

Concentrations of imperiled taxa with a listing status under the Endangered Species Act are found across the country, with particular concern in Peninsular Florida and Hawaii for birds, and in the RPA North and South Regions for fishes, crayfish, and mussels.

Increasing numbers of species across taxa are being listed under the Endangered Species Act, with few species delisted due to conservation. Current patterns of distribution reflect cumulative counts of federally listed imperiled species over time. Concentrations of federally listed imperiled taxa are found across the country, with hotspots in Peninsular Florida and Hawaii for birds, and in the North and South Regions for fishes, crayfish, and mussels. Among forest-associated species, the greatest proportion of possibly extinct and at-risk species is found among amphibians.

Watersheds of the RPA North and South Regions are most vulnerable to compounded land use stress. Regardless of RPA region, development stands out as the largest overall land use stressor for native ecosystems.

Land use pressures including land conversion, human population growth, expansion of agricultural areas, and development of energy infrastructure and mining are most pronounced in watersheds of the Eastern United States, specifically the RPA North Region and areas of the South Region, where fewer Federal lands exist to fill the role of ecological reserve. Managers in the East may therefore face more intense land use pressures than in the West, where increased pressures are associated with population and agricultural centers in Washington, Idaho, California, and pockets of the Rocky Mountains. This spatial pattern varies from climate-driven stress, which is generally highest in the North and Pacific Coast Regions.

Areas of potential high climate stress were consistently found in mountainous areas of the RPA North, Rocky Mountain, and Pacific Coast Regions, with pockets of stress identified in arid regions of the Rocky Mountain Region.

Climate change is affecting terrestrial and aquatic habitats in the United States, resulting in large-scale shifts in the range and abundance of native fauna. Projections identified several areas where a majority of the plausible futures predict high stress for native species in response to climate change: mountains in the Pacific Coast, Rocky Mountain, and South Regions; large areas from New York to Maine in the North Region; and lower elevation lands in southern New Mexico, southern Arizona, Oklahoma, and Texas. The consistency of high stress in these areas suggests that wildlife managers will likely see changes in wildlife habitat and wildlife distributions. Areas of high elevation throughout the Pacific Coast and Rocky Mountain Regions are projected to experience high stress under the both the RPA hot and dry model projections. Higher elevations in the eastern part of the conterminous United States appear to experience more stress under hot projections than dry projections.

Federal lands with a lower risk of development or land conversion, such as those managed by the National Forest System and U.S. National Park Service, are projected to be under higher climate stress compared with other lands, potentially limiting their future ability to function as climate refugia for native biota.

National Forest System and U.S. National Park Service lands contain many federally listed species, making them critical for the protection and recovery of imperiled biota. However, these lands are projected to experience greater climate stress than the rest of the country due to factors such as their locations, often in higher elevations. Thus, climate-driven stress projected for Federal lands may limit their future ability to function as refugia. This becomes particularly relevant when land use change projections for private land across much of the country anticipate permanent conversion to developed land use.

Outdoor Recreation and Wilderness

Publicly managed recreation resources, at all levels of government, provide most opportunities for outdoor recreation.

The recreation opportunities offered by governments vary in their types, natural settings, and locations relative to population centers. For those living in or visiting urban and peri-urban areas, local public lands generally offer the most-accessible spaces for nature-based outdoor recreation. Local government public lands typically offer opportunities to engage in the most-popular outdoor recreation activities, such as walking/hiking, viewing nature and wildlife, and simply relaxing in the outdoors, and often accommodate those with a wide range of skills and abilities. State park agencies and other State-level agencies focused on forestry, wildlife, land conservation, or other natural resources also provide public recreation opportunities. There are more than 2.2 million acres of State park land across the United States. Among RPA regions, the North Region has the greatest number of State park acres. Seven Federal agencies provide

the majority of recreation opportunities on nearly 400 million acres of federally managed lands. In general, Federal lands are most common in the West but are present in every RPA region. Private lands are less accessible and most opportunities on these lands accrue to landowners.

Per capita participation in outdoor recreation activities has been relatively stable in recent years but population growth has led to an increase in the number of participants.

About 50 percent of the U.S. population engages in outdoor recreation. That participation rate has remained stable since 2007, before increasing to about 54 percent of the population in 2020. Of the activities commonly associated with forests, rangelands, and other open spaces, hiking, camping, and freshwater fishing are consistently the most-popular, with between 13 and 15 percent of the population engaging in those activities. Before 2020, participation had been increasing slightly for hiking, declining for camping, and remaining steady for fishing. Although participation rates have been mostly steady, the number of outdoor recreation participants has increased with a growing U.S. population. Between 2008 and 2018, an additional 15 million people engaged in outdoor recreation, with most of that increase attributed to hiking, which had a net increase of 18 million participants.

Forest recreation resource availability per capita is expected to continue to decline in future decades for locations experiencing population growth.

Declines in the per capita availability of forests for recreation are projected under moderate and high levels of future economic and population growth. In these RPA scenarios, projected losses in per capita non-Federal forest area are found in every RPA region and are most significant in the far north of the North Region, the northern portions of the Pacific Coast Region, and the southern portions of the Rocky Mountain Region. Some gains in per capita non-Federal forest recreation area are projected under scenarios with lower future economic and population growth. When gains are projected to occur, they are most common in the northern areas of the North and Rocky Mountain Regions. Federal forest recreation area has been generally stable over the last several decades and is not projected to grow substantially. In the presence of continued population growth, however, per capita area of Federal forests is projected to decline. Likewise, the area of State-managed forests in the United States has remained steady in recent years and is not expected to grow. There have been some gains in the size of U.S. State park systems in recent years, but most of those gains appear to trace to administrative changes among State agencies rather than expansion of the area under State ownership.

Greater income and population growth generally result in higher rates of per capita participation in outdoor recreation.

Modest changes (frequently declines) in per capita participation rates in outdoor recreation are projected for the coming decades. In general, projected per capita participation is greater under RPA scenarios that assume the highest income growth. The exceptions to that pattern are hunting, motorized off-road recreation, and developed site camping, where projected per capita participation is lowest under the highest rates of income and population growth. The greatest numbers of participants are projected under the highest income and population growth RPA scenarios for almost all activities and for all RPA regions. In many cases, the high rates of population growth in the RPA scenarios overwhelm any projected declines in per capita participation rates, increasing the total number of participants. This is especially true in regions like the RPA South, where we project large population gains in future decades.

Continued population growth results in a greater number of outdoor recreation participants, even potentially offsetting any declines in per capita participation.

The number of participants engaging in a recreation activity in the future reflects both changes in per capita participation over time and the size of the future population. Although there may be meaningful changes (increases or decreases) in per capita participation and average number of days of engagement for individual activities (the per capita consumption measure for recreation), population growth typically magnifies (for increases) or offsets (for decreases) those changes. Projected national and regional losses in the numbers of participants engaging in activities in 2040 and 2070 relative to 2012 are primarily confined to the high warming-low U.S. growth RPA scenario (HL). Potential declines in the numbers of participants in 2040 and 2070 extend into the high warming-moderate U.S. growth scenario (HM) nationally and for several regions for hunting, motorized snow use, cross-country skiing and snowshoeing, and floating. Projected declines in participation for hunting extend into the high warming-high U.S. growth scenario (HH) in the RPA North Region, reflecting the steep projected decline in per capita hunting participation in the face of both high atmospheric warming and strong population and economic growth.

Greater atmospheric warming is projected to have a negative influence on recreation engagement in many activities and little positive influence.

Participation rates in 6 of 17 activities exhibited marked responsiveness to the level of future atmospheric warming. In all cases, future climatic change, as influenced by increasing levels of atmospheric warming, led to lower participation rates and reductions in the average number of times each year that people recreate across all climate futures. Motorized snow use and cross-country skiing and snowshoeing were the activities that exhibited the greatest negative response to higher atmospheric warming. Within the RPA scenarios and their associated assumed level of atmospheric warming, the specific RPA climate projections also influenced participation in outdoor recreation in many activities. When unique patterns were present, they most frequently occurred for the hot, dry, and least warm climate futures. Although there is generally a lot of variability across the activities, hot and dry climate futures tend to yield lower participation rates, while the least warm climate future tends to yield higher participation rates.

Projections of consumption, measured as annual days of recreation, show increases across most activities, with the greatest numbers of recreation days in activities of a general or broadly accessible nature, i.e., day hiking, viewing nature, developed site use, and developed site camping.

Continued growth is projected in the total number of days of engagement annually in outdoor recreation. Growth in days of engagement is projected despite projected declines in the average number of days that each participant recreates. The projected growth in days of recreation is largely determined by the magnitude of projected population increase, and thus the number of potential recreationists. For almost all activities, the projected growth in the number of recreation participants overwhelms any projected changes in the average number of days spent recreating per participant. Total days of engagement in outdoor recreation activities are therefore projected to be greatest when projected population is greatest. Day hiking, viewing nature, developed site use, and developed site camping are projected to account for the greatest numbers of days of recreation in future decades, consistent with current patterns.