Chapter 3
Future Scenarios

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The Resources Planning Act (RPA) Assessment uses a set of scenarios of coordinated future climate, population, and socioeconomic change to project the availability and condition of renewable resources over the next 50 years. Since its inception in 1974, RPA Assessments have always looked 5 decades into the future, but approaches have varied. Before the 2010 RPA, futures generally were constructed based on consensus views on key socioeconomic variables affecting demands for goods and services from forests and rangelands, resulting in one likely future. Variations on that future were explored but limited in scope (e.g., low and high population growth), and were often focused on variables specific to forest product markets (e.g., low and high housing starts and alternative assumptions about softwood imports from Canada). Given rapid globalization in recent decades, these limited socioeconomic "futures" became insufficient to address the forces driving natural resource change nationally.

Beginning with the 2010 RPA Assessment, a set of integrated scenarios has been used to frame the resource analyses. This approach and analytical framework were designed to better incorporate global linkages and interactions between natural resources, extend our analytical capability to evaluate the potential effects of climate change, and more clearly the describe complexity and uncertainty associated with projecting future conditions and trends (USDA Forest Service 2012). We continue this approach to develop scenarios for the 2020 RPA Assessment. These scenarios depict coherent interdependent futures for global and U.S. population dynamics, socioeconomic factors, and climate change. They also provide qualitative and quantitative inputs to the RPA domestic resource analyses, which project resource conditions and trends to 2070. The scenarios used in the 2020 RPA Assessment are described in this chapter.

Key Findings

- The RPA Assessment analyzes the potential effects of global and national trends on all U.S. forest and rangelands over the next 50 years.
- A carefully selected set of scenarios, defining and integrating plausible future climate, population, and economic conditions, are used to organize projection work.
- All resource areas (e.g., forests, water, recreation, and wildlife) use the same set of scenarios or a subset (e.g., climate only) to define a plausible range of natural resource availability and condition over a 50-year period, establishing a consistent and coordinated approach.
- The downscaled projections of socioeconomic and climatic change developed from the scenarios can be used alongside RPA resource projections to inform planning, strategic thinking, and policy deliberation about the future for natural resource management and policy needs.

Framing the RPA Assessment Scenarios

Scenarios are used to explore alternative futures and are intended to provide a framework for objectively evaluating a plausible range of future resource outcomes. This approach is particularly useful when there is considerable uncertainty about the trajectories of the driving forces behind political, economic, social, and ecological changes (Alcamo et al. 2003, IPCC 2007). A globally linked scenario approach is important for the RPA Assessment because global conditions and trends in these variables increasingly affect domestic natural resources. Well-defined global scenarios provide a coherent framework for evaluating outcomes across resource analyses. Consistency in their construction allows managers and policymakers a deeper understanding of the connections and interactions among these variables as well as insight into potential options for enhanced adaptation or mitigation.

A scenario approach can use both qualitative and quantitative methods to visualize alternative futures based on different socioeconomic or institutional assumptions. The use of the term “scenario” can be confusing because scenarios are used for various purposes, or in reference to specific types of scenarios (see Moss et al. 2008, USGCRP 2010). For the RPA Assessment, we have adopted the approach used by the Intergovernmental Panel on Climate Change (IPCC). The scenarios represent plausible futures to better understand how systems may respond to different rates of change or how different decisions may alter resource trajectories (Moss et al. 2008). Scenarios are not assigned likelihoods, nor are any scenarios intended to be “accurate” per se. Rather, these constructed scenarios provide a means of qualitatively and quantitatively understanding how a range of socioeconomic and climate conditions could interact through time to create different natural resource futures. Scenarios are ultimately used to derive socioeconomic and climate projections, which refer to model-derived estimates of the future.

Although we reviewed and considered global scenarios constructed by other research groups (see Kok et al. 2015 for an evaluation of global scenarios), we selected the combination of the IPCC-based climate and socioeconomic scenarios as the basis for the 2020 RPA Assessment for several reasons. These scenarios provide quantitative data on both climate and socioeconomic variables over our assessment time horizon, are well documented in the scientific literature, have been widely used across a large range of impact studies, and were more current at the time of selection than other options.

The 2020 RPA Assessment relies on the approach used in the IPCC Fifth Assessment Report (AR5) (IPCC 2014) to provide global context and quantitative linkages between U.S. and global trends. Unlike the sequential approach for scenario development used in the IPCC Third and Fourth Assessment Reports, AR5 used a parallel process (Moss et al. 2010): four scenarios representing alternative climate futures (Representative Concentration Pathways or RCPs) were developed independently of five socioeconomic scenarios (Shared Socioeconomic Pathways or SSPs) (Nakićenović et al. 2014, O’Neill et al. 2014). The range of scenarios considered in the IPCC AR5 provided a broad spectrum of potential futures. We integrated RCP and SSP scenarios to ensure that the degree of atmospheric warming indicated by the RCP is consistent with the emissions generated by the socioeconomic activity depicted in the SSP storyline, and that the integrated scenarios do not indicate large departures from current natural resource policies.

The remainder of this chapter describes the process used to select and integrate two global climate and four global socioeconomic scenarios from AR5 into four RPA scenarios

Table 3-1. Characteristics of the four 2020 RPA Assessment scenarios.[a]

Characteristic	Scenario LM	Scenario HL	Scenario HM	Scenario HH
Global warming and U.S. socioeconomic growth	Lower warming and moderate U.S. growth	High warming and low U.S. growth	High warming and moderate U.S. growth	High warming and high U.S. growth
Global real GDP[b] growth, 2020–2070	Medium (4.9X)	Low (3.2X)	Medium (4.6X)	High (6.9X)
Global population growth, 2020–2070	Low[c] (1.2X)	High (1.6X)	Medium (1.4X)	Low (1.2X)
U.S. real GDP growth, 2020–2070	Medium (3.0X)	Low (1.9X)	Medium (2.8X)	High (4.7X)
U.S. population growth, 2020–2070	Medium (1.5X)	Low (1.0X)	Medium (1.4X)	High (1.9X)
Global emissions	Lower	High	High	High
Global scenario links	RCP 4.5-SSP1	RCP 8.5-SSP3	RCP 8.5-SSP2	RCP 8.5-SSP5

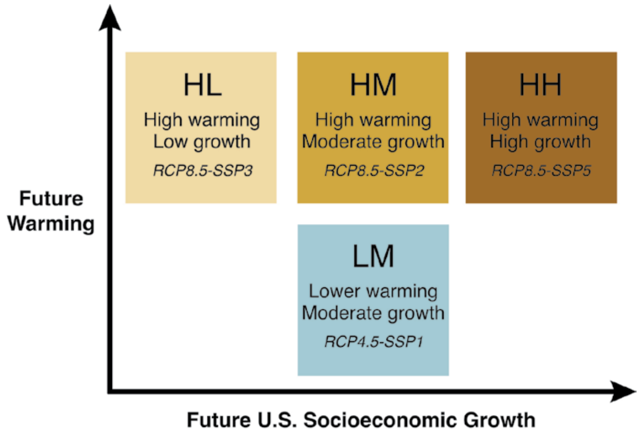
[a] *Numbers in parentheses are the factors of change in the projection period. For examples, U.S. real gross domestic product increases by a factor of 3.0 between 2020 and 2070 in Scenario LM.*

[b] *GDP = gross domestic product (based on estimates by the International Institute of Applied Systems Analysis 2019).*

[c] *Note: Low population involves initial increase with declines in the latter decades of the projection period.*

Source: Langner et al. 2020.

Figure 3-1. Characterization of the 2020 RPA Assessment scenarios in terms of future changes in atmospheric warming and U.S. socioeconomic growth. These characteristics are associated with the four underlying Representative Concentration Pathway (RCP) – Shared Socioeconomic Pathway (SSP) combinations.



Source: Langner et al. 2020.

(table 3-1, figure 3-1), and then downscale associated global climate and socioeconomic projections to a fine-scale resolution across the United States. Scenario "short names" are defined based on the climate scenario's global radiative forcing levels (first letter) and the socioeconomic scenario's U.S. growth characteristics (second letter), as described in the first line of table 3-1. The term "socioeconomic growth" is mainly focused on the rate of positive growth in aggregate economic output and in aggregate disposable personal income in the United States. The rate of population growth differs from the rate of economic growth in each scenario, although the two align in their general trajectories. Similar to the U.S. National Climate Assessment (USGCRP 2017) we label the RCP 4.5 climate scenario as "lower warming" and the RCP 8.5 climate scenario as "high warming." The four RPA scenarios are: lower warming-moderate U.S. growth (LM), high warming-low U.S. growth (HL), high warming-moderate U.S. growth (HM), and high warming-high U.S. growth (HH). The selected scenarios set the socioeconomic and biophysical bounds for evaluating resource futures in the 2020 RPA Assessment. A more extensive description of RPA scenario development is available in Langner et al. (2020).

Climate Scenarios for the 2020 RPA Assessment

In this section we describe the process used to select global climate scenarios and a manageable set of climate projections for the 2020 RPA Assessment. More details can be found in Joyce and Coulson (2020) and Langner et al. (2020).

Global Climate Scenarios

For the IPCC AR5, Representative Concentration Pathways (RCPs) based on radiative forcing represent global climate scenarios (Moss et al. 2010, USGCRP 2017). Radiative forcing is a change in energy flux of the atmosphere (warming or cooling) over time. Between 1750 and 2019, natural and anthropogenic factors have increased radiative forcing by 2.72 Watts/square meter (W m^{-2}), causing the atmosphere to warm during this period (IPCC 2021). RCPs were designed to explore possible climate futures over a wide range of emission levels and the consequences of future increases in radiative forcing by 2100. Components of radiative forcing used as inputs for climate modeling include emissions of greenhouse gases, air pollutants, and land use (van Vuuren et al. 2011). A large radiative force implies a larger change in the climate. Four RCPs were defined by different levels of future radiative forcing: a very low forcing level (RCP 2.6, or 2.6 W m^{-2}); two medium stabilization scenarios (RCP 4.5 and RCP 6.0); and one high forcing level (RCP 8.5) (IPCC 2014).

For the 2020 RPA Assessment, we chose to follow the Fourth National Climate Assessment approach for framing impacts of climate change by using RCP 4.5 and RCP 8.5 as the two bounding climate pathways for RPA projections (Joyce and Coulson 2020, Langner et al. 2020). From a scientific viewpoint, exploring all available alternative futures is desirable. But resource and time constraints, as well as communication challenges, required a narrowing of choices for the RPA Assessment. RCP 2.6 was not included in the RPA Assessment analyses because extensive mitigation policy is required to achieve this lower radiative forcing level, and the RPA Assessment focuses on futures with no significant change from current policy. We also did not consider RCP 6.0 because resource effects from that scenario are likely to fall between RCP 4.5- and RCP 8.5-based analyses. Using both a lower-end and a higher end scenario, RCPs 4.5 and 8.5 respectively, provides a wide range of long-term outcomes.

National Climate Projections

Resource and time constraints also affected the number of climate models and projections selected. Climate modeling institutions across the world have used the RCP data to undertake coordinated experiments with different global climate models. As a result, there are 20 or more climate projections per RCP available as part of the Coupled Model Intercomparison Project, Phase 5 (CMIP5) (https://esgf-node.llnl.gov/projects/cmip5/) (Hayhoe et al. 2017, Knutti and Sedlack 2013). To choose a set of climate models and associated downscaled projections for the 2020 RPA Assessment, we first identified the climate variables needed for the resource analyses and then developed criteria for selecting the climate models and the projections (Joyce and Coulson 2020, Langner et al. 2020).

Based on the resource analysis needs of the 2020 RPA Assessment, the downscaled dataset selected was MACAv2-METDATA (Abatzoglou 2013, Abatzoglou and Brown 2012). This dataset contained statistically downscaled projections from 20 different global climate models, each run under RCP 4.5 and RCP 8.5. The spatial resolution for this downscaled dataset was 4 km (2.5 miles), meeting the fine-scale needs for RPA Assessment resource analyses. Because the RPA Assessment focuses on the next 50 years (through 2070), we selected models that provided temperature and precipitation for this entire period, defining change as the difference between the future period (2041 to 2070) and the historical period (1971 to 2000).

Three criteria were used to screen individual climate models (Joyce and Coulson 2020). The first criterion was historical model performance to eliminate from further consideration those models consistently rated as poor performers (Rupp 2014, 2016, Rupp et al. 2013). The second criterion was that only one model from a modeling institution was selected to reduce the influence of modeling institution on the projections. The third criterion was to choose the same model for RCP 4.5 and RCP 8.5, if possible, to reduce model variability across the RCPs.

We selected five climate models that capture the full range of temperature and precipitation projections across the entire set of models. Ensembles that average projections across models, thereby reducing variability, have often been used to reduce the number of projections. We chose not to use an ensemble, because the individual model variability may be important when these projections are used as inputs in resource modeling efforts such as for water, forest condition, rangelands, and wildlife. We identified four projections that represented the least change and the greatest change in temperature (least warm, hottest) and the largest decrease and greatest increase in precipitation (driest, wettest) for the conterminous United States. Although these models each represent the magnitude of change for one climate variable, knowledge of what each model projects for the other climate variable (Joyce and Coulson 2020) is important for proper application of the information: models selected to represent the magnitude of change for one climate variable (such as temperature) may not project the mid-range value for the other climate variable (such as precipitation). A fifth projection was selected that was close to the mean change in temperature and precipitation of all model projections. We were able to select the same models for both RCP 4.5 and RCP 8.5 for all variables.

This set of five models provides a reasonable approximation of the overall projected temperature and precipitation space encompassed by the larger set of 20 models, but a greatly reduced total effort, thereby making the subsequent analysis feasible (table 3-2). Monthly downscaled projections for the conterminous United States were obtained and archived in the U.S. Department of Agriculture, Forest Service's Research Data Archive, along with the historical climate observations that were used in the MACA downscaling process (Coulson and Joyce 2020, Joyce et al. 2018); downscaled daily projections are available on request.

Although beyond the scope of the 2020 RPA Assessment, Joyce and Coulson (2020) also evaluated the utility of the RPA climate model selections for behavior at end of century (2070 to 2099) and for regions of the National Forest System (NFS). See the sidebar Using Scenarios and Projections in Resource Management Planning for a description of how planners might think about using climate projections. See Joyce and Coulson (2020) for more detailed information about the selection and utility of RPA climate model selections.

Socioeconomic Scenarios for the 2020 RPA Assessment

In this section we describe the process used to select global socioeconomic pathways and create nationally downscaled socioeconomic data for the 2020 RPA Assessment. More details on scenario selection can be found in Langner et al. (2020), and more information on the downscaling process can be found in Wear and Prestemon (2019a).

Global Socioeconomic Scenarios

Shared Socioeconomic Pathways (SSPs) were developed in parallel to the RCPs to provide scenarios of plausible societal development in support of the IPCC assessment process (O'Neill et al. 2014). They consist of distinct storylines that capture uncertainty about the future across

Table 3-2. Climate model projections selected to reflect different U.S. climate futures in the year 2070.

	Least warm	Hot	Dry	Wet	Middle
Climate model	MRI-CGCM3	HadGEM2-ES	IPSL-CM5A-MR	CNRM-CM5	NorESM1-M
Institution	Meteorological Research Institute, Japan	Met Office Hadley Centre, United Kingdom	Institut Pierre Simon Laplace, France	National Centre of Meteorological Research, France	Norwegian Climate Center, Norway

Source: Joyce and Coulson 2020.

Using Scenarios and Projections in Resource Management Planning

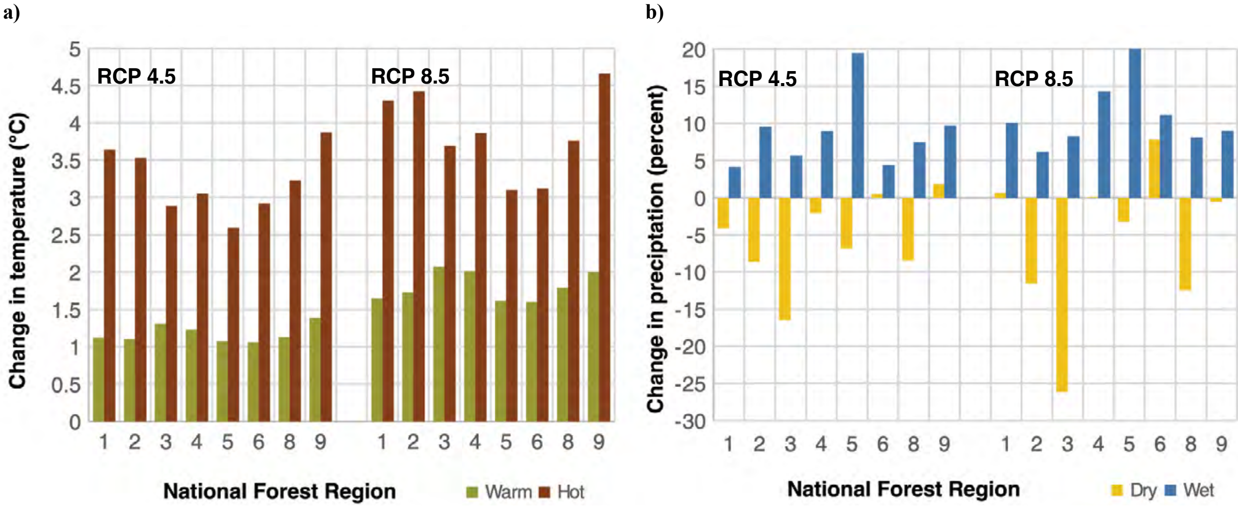
Climate change will continue to affect the natural resources and ecosystem services that are managed by Federal, State, and private landowners. Managers have a long experience with their local weather, climate, and resource conditions; the challenge is anticipating how future climate change will affect the resources. Just as historical observations can give a picture of past climate, monthly and annual climate projections can offer a plausible future climate, based on assumptions about atmospheric warming related to emissions, land use change, and our understanding of the Earth system. Working with a set of plausible future climate projections can facilitate identifying future risks, both in terms of future climate outcomes as well as the transitions that lead to those outcomes.

Land managers and planners might first ask how far in the future is information needed—5 years, 50 years, or 80 years? For example, because trees can live longer than 50 years and infrastructure planning often extends beyond the next decade, examining the more distant future climate might be important. Model selection for the RPA scenarios was based on behavior through 2070 but our analysis concluded that the same core models could be used to capture the range of climate futures for an end-of-century analysis (2070 to 2099). Managers and decisionmakers might also consider possible transitions from today's conditions to the alternative outcomes depicted by the RPA scenarios and climate projections. Many changes occur as systems encounter thresholds and transition from one state to another, sometimes with extreme consequences and needs for rapid, even large-scale interventions. Understanding and navigating these transitions can create additional opportunities for mitigation and adaptation.

Planners and managers might also ask which and how many plausible futures to examine. An overwhelming number of climate projections are available, and each projection offers insight into the future. The ensemble (or average of many projections) is often used to capture the trend; however, individual model variability may be important in managing risks to resources. RPA projections were selected with the objective of identifying a feasible set of projections that describe the range of future climates—hot, least warm, dry, wet, and middle—to represent the bounds of the most likely climate outcome based on our current knowledge. Examining this range of futures can allow planners and managers to assess potential future vulnerabilities and possible worst-case scenarios. Resource managers can also compare their past experiences with a plausible future. For example, if the recent climate has been hot, exploring the "hot" projection allows examination of the additional stress that could be placed on the resource in the future.

Figure 3-2. Relative comparisons of change by mid-century (2041 to 2070) from the historical period (1971 to 2000) between RPA climate model projections across National Forest System regions for (a) temperature and (b) precipitation under (left) RCP 4.5 and (right) RCP 8.5. Figures show that in all NFS regions: (a) the hot RPA projection (HadGEM2-ES) is always hotter than the least warm projection (MRI-CGCM3) and (b) the wet RPA projection (CNRM-CM5) is always wetter than the dry projection (IPSL-CM5A-MR).

a) **b)**

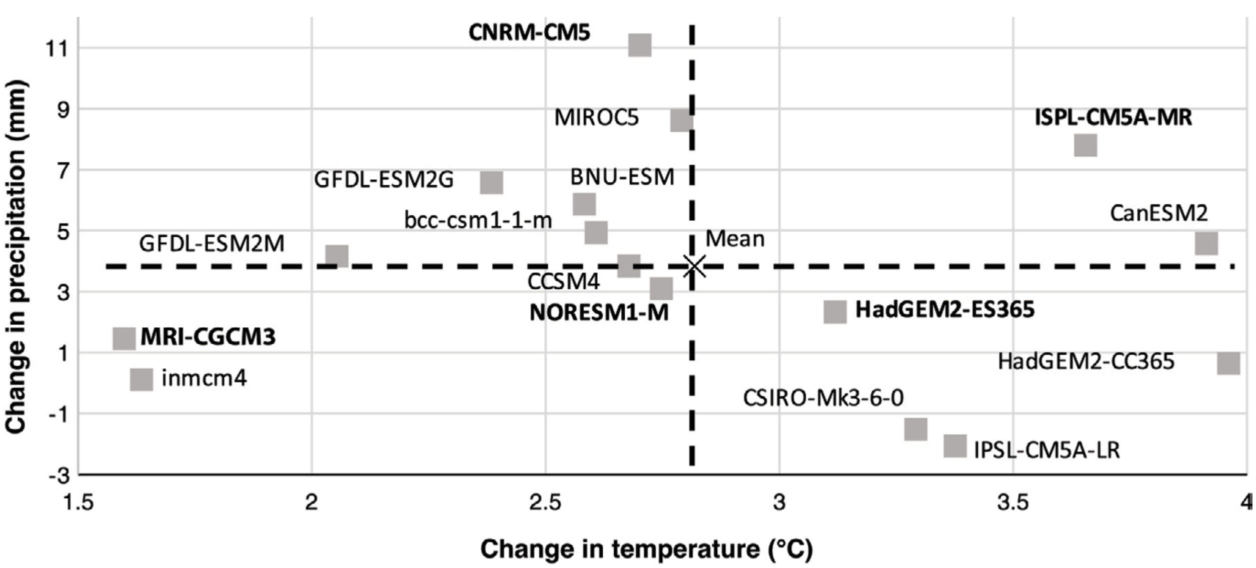


RCP = Representative Concentration Pathway.

RPA projections were selected based on results for the conterminous United States, but planners might instead be focused on a more specific spatial extent, such as a National Forest System (NFS) region (Joyce and Coulson 2020). Do the RPA projections represent the same climate futures at the regional scale? Regional climates vary greatly across the United States—for example, the dry Southwest and the wet Pacific Northwest. At the NFS regional scale, the relative comparisons are appropriate for all regions: the hot RPA projection is always hotter than the least warm projection and the wet projection is always wetter than the dry RPA projection in each region (figure 3-2). Consequently, projections used in this report have comparative value for NFS regions; however, alternative projections might be preferable for individual NFS regions. Joyce and Coulson (2020) analyzed all 20 MACAv2-METDATA climate models by NFS region to determine whether a different model might produce better absolute results for a given NFS region. In some situations, a different climate model was a better representative of the range within the region. For example, while the RPA wet model projects wetter conditions than the dry model in all NFS regions, the dry model projects wet conditions for NFS Region 6 (Pacific Northwest) while other climate models project a very dry future (figure 3-3). The relative comparisons between the wet and dry projections are appropriate for NFS Region 6, but planners and managers for this region may want to examine a different projection to specifically plan for a dry future. We direct planners and managers to the analysis in Joyce and Coulson (2020) to explore the relative ranking of climate models at the regional scale, but encourage use of the RPA climate model selections when possible as this also enables use of the associated RPA resource projections.

These climate projections, alongside socioeconomic projections and future land use projections, are used in the RPA Assessment chapters to project plausible future condition and availability of renewable resources. In addition to temperature and precipitation change, other climate variables are part of the climate dataset (such as potential evapotranspiration) and have been used in projecting the influence of future drought on resource availability. In addition to using climate projections directly as described here, managers and planners can examine the socioeconomic projections described later in this chapter, as well as the associated resource projections throughout the RPA Assessment to assess the plausible range of vulnerabilities and possible worst-case scenarios in future resource availability and condition. The projections provided throughout the 2020 RPA Assessment are based upon the same core scenarios and rely on the same five climate models—all selected to encompass the range of plausible socioeconomic and climatic futures. Resource projections can therefore also be interpreted and implemented as described above (e.g., examining future resource condition and availability specifically associated with lower or high atmospheric warming, different levels of future socioeconomic growth, and different climate futures).

Figure 3-3. Projected changes for NFS Region 6 (Pacific Northwest) in annual precipitation (percent) at mid-century (2041 to 2070) from the historical period (1971 to 2000) under RCP 8.5. While the RPA dry model (IPSL-CM5A-MR) projects a drier future than the RPA wet model (CNRM-CM5), the dry model does project an increase in precipitation at mid-century, and there are many models which project a decrease in annual precipitation in this region. Model names in bold are the national core RPA models for mid-century: least warm—MRI-CGCM3; hot—HadGEM2-ES; dry—IPSL-CM5A-MR; wet—CNRM-CM5; middle—NORESM1-M.



several variables: population, economic growth, technology, trade, and governance. Five SSPs were developed, with each described in terms of the challenges, costs, research and development investments, and degree of policy changes involved in mitigating or adapting to climate change. Four of the SSPs describe the range of high challenges (difficult, costly, and entailing large policy shifts) and low challenges for global adaptation and mitigation, while a fifth SSP defines an intermediate case. Although the SSPs capture a range of future levels of socioeconomic growth, no SSP envisions a future that entails sustained negative growth. The SSPs do not include climate feedbacks or specific policy options (O'Neill et al. 2014).

Three different modeling groups developed country-level projections of both population and income consistent with SSP global narratives. For the 2020 RPA Assessment, we relied on the economic projections provided by the International Institute for Applied Systems Analysis (Cuaresma 2017, IIASA 2018) because IIASA included more country-level projections that are important for modeling international trade flows as applied in RPA modeling of global wood products markets. To develop national socioeconomic projections linked to the global SSPs for use in the RPA Assessment, we focused on SSP variation in demographic and economic characteristics, which have been quantified at the country level (data available on the SSP public database at https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=welcome).

Global and U.S. trends do not necessarily follow the same trajectory across SSPs: global population trends and U.S. population trends diverge, while U.S. trends in GDP growth are more consistent with global trends (Langner et al. 2020). These patterns are tied to several interacting assumptions about economic growth, fertility and mortality, migration patterns, and the openness of the global economy. As with our climate pathway and projection selections, resource and time constraints limited the number of SSPs selected. After performing the downscaling analysis described in the next section, we selected four of the five SSPs to capture the magnitude of change in socioeconomic conditions across the entire set (Langner et al. 2020). We chose SSP3 and SSP5 because they bound the demographic and economic change (low and high change, respectively) for the United States and capture most of the range in global change as well. SSP1 and SSP2 follow similar trajectories for the United States and globally; however, the underlying narrative for these pathways offers opportunities to explore differences among resource- and sector-specific variables that could have different implications for natural resources. For example, the narrative for SSP1 is focused on low-emission energy sources, whereas SSP2 is more tightly linked to historical patterns of energy use. Therefore, we decided to retain both SSP1 and SSP2. We eliminated SSP4 because its trajectory falls between SSP3 and SSP2.

National Socioeconomic Projections

Considerable effort by the climate science community devoted to downscaling climate projections eliminated the need to develop our own downscaled climate data for the 2020 RPA Assessment. No similar effort had been devoted to socioeconomic scenarios—specifically to jointly downscaling the SSP-based population and economic projections. Projections of population and income that are downscaled using a consistent approach are critical inputs to various RPA modeling systems because they play a central role in determining natural resource demands and impacts across the United States; we therefore developed a methodology to downscale the country-level SSP data to a finer spatial scale (Langner et al. 2020, Wear and Prestemon 2019a). This approach was based on economic theory and is consistent with county-scale historical patterns of change (Wear and Prestemon 2019a). Although these projections capture recent historical trends in climate, they do not explicitly account for changing climate variables when projecting to 2070, resulting in considerable uncertainty, particularly in the latter years of the projections. Rising sea levels, extended droughts, and extreme heat could potentially alter not just the magnitude but also the direction of historical trends, which is not incorporated into existing projections. We hope to examine the possible implications of directional changes in historical trends through future research.

We applied the methodology to estimate county-level projections for all five SSPs (Wear and Prestemon 2019a). In these projections, the rate of personal income change nationwide (summed across all counties) was constrained to match the rate of GDP change nationwide as projected by IIASA (2018) for the United States for each of the SSPs. Under SSP3, population grows slowly to a peak in 2035 and then gradually declines to 2010 population levels by 2070, while income grows steadily at about 1 percent per year (from about $13 billion in 2010 to about $24 billion in 2070). Under SSP5, population expands by 86 percent, from 313 million to 581 million between 2010 and 2070, while real GDP grows at a rate of 2.5 percent per year between 2010 and 2070, more than quadrupling over this period. SSPs 1, 2, and 4 provide intermediate projections with population growing to between 390 million and 451 million people in 2070 and annual GDP growth rates of between 1.4 and 1.8 percent.

In terms of population, we project a shift in the Nation's population away from the Northeast and Midwest and toward the South and West, although the rates of such interregional population shifts vary across SSPs; the smallest shifts occur under the lowest population growth rate. Projections indicate that a large share of the current rural United States will experience either new or continued population losses or stable population across all scenarios while urban areas expand (see Wear and Prestemon

2019a for details). As described above, only downscaled socioeconomic projections for SSPs 1, 2, 3, and 5 were used to support resource projections in the 2020 RPA Assessment. The observed county-level population and personal income data from 2010 and projections over the 2015 to 2070 period used in the 2020 RPA Assessment are archived in the USDA Forest Service's Research Data Archive (Wear and Prestemon 2019b).

2020 RPA Scenarios

RPA scenarios were constructed by linking the RCPs (climate futures) with SSPs (socioeconomic futures). The RCPs and SSPs were developed to provide a scenario matrix architecture to assist in the development of common scenarios that can be used across different climate change research communities. While the RPA Assessment scenarios need to link to the general worldviews of the RCP and SSP futures, they also must provide a compelling range of futures for the United States and be available at the fine spatial scale needed to match the economic and ecological context of the RPA resource analyses.

As described above, RCPs 4.5 and 8.5 were selected as low and high bounding pathways to capture the range of plausible warming futures, and SSPs 1, 2, 3, and 5 were selected to capture the range of socioeconomic change; this resulted in eight possible RCP-SSP combinations for the 2020 RPA Assessment scenarios. When paired with the five climate projections, we were facing 40 potential future socioeconomic-climate outcomes for the United States—exceeding the analytical capacity of the Assessment. However, not all potential RCP-SSP combinations could be plausibly linked (Riahi et al. 2017). To link an RCP and SSP into an integrated scenario, the degree of atmospheric warming indicated by the RCP must be consistent with the emissions generated by the socioeconomic activity depicted in the SSP storyline. Because the RPA Assessment analyses are based on continuation of current policies, we selected RCP-SSP combinations that did not require assumptions that would indicate large departures from current policies for the RPA Assessment scenarios (Langner et al. 2020).

We paired RCPs and SSPs using the following logic. SSP1 is the only baseline scenario that resulted in radiative forcing close to the RCP 4.5 level and was judged to be the only SSP that could plausibly link with RCP 4.5 for RPA Assessment purposes. Combining any of the remaining SSPs with RCP 4.5 would require varying levels of technology or policy assumptions that are beyond the scope of RPA Assessment analyses except when the RPA framework is used specifically for policy analysis. SSP5 can be plausibly linked with RCP 8.5 for Assessment purposes. The remaining SSPs—SSP2 and SSP3—produced forcing levels between RCP 6.0 and RCP 8.5. Because we paired these SSPs with RCP 8.5-based climate projections, our results could overstate climate influence.

We acknowledge that many pairings might be plausible (assessing the mutual consistency of their assumptions is inexact); however, we selected four RCP-SSP combinations to underpin 2020 RPA Assessment analyses of resource effects without significant policy changes (table 3-1, figure 3-1). The four 2020 RPA Assessment scenarios encompass most of the projected range of climate change from the RCPs and projected quantitative and qualitative range of socioeconomic change from the SSPs, resulting in four distinct futures that vary across a multitude of characteristics (figure 3-4). The range of changes in global and U.S. characteristics is similar between the 2010 and 2020 RPA Assessment scenarios. For the United States, economic and population growth trends initially move in the same direction across scenarios (with population growth turning to shrinkage under SSP3 for the United States after 2040), whereas globally, economic and population growth diverge in three of the four scenarios. These quantitative trends and narratives provide a unifying framework that organizes the RPA Assessment natural resource sector analyses around a consistent set of possible world views.

Linking 2020 RPA Assessment Scenarios to Natural Resource Sectors

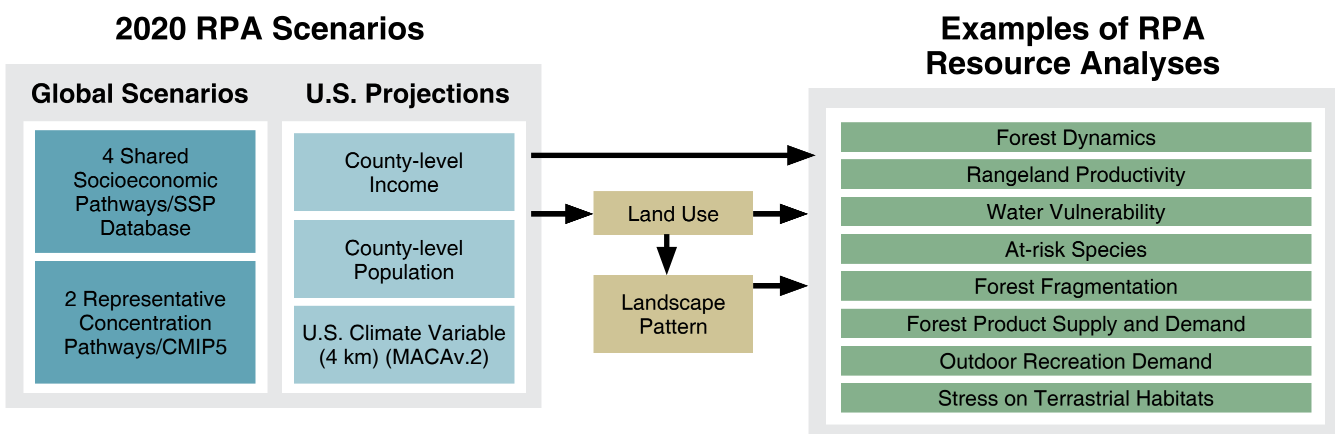
Defining the 2020 RPA Assessment scenarios is the beginning of the RPA analysis process. The RPA scientists then determine how to use the scenario data and assumptions in their resource sector analyses. Each analysis uses different combinations of the scenario variables and resource-specific variables to evaluate future resource outcomes. Examples of connections between components of the 2020 RPA Assessment scenarios and RPA Assessment resource analyses (figure 3-5) illustrate the numerous routes through which the scenario variables can influence resource analyses. In some cases, both socioeconomic and climate projections are direct inputs to resource analyses, including outdoor recreation demand, water vulnerability, and forest product supply and demand. In other cases, only the climate variables are direct inputs to the analyses, for example, in projections of rangeland productivity and stress on terrestrial habitats.

Land use and landscape pattern projections are often the intermediary between the scenarios and resource-specific effects (figure 3-5). The land use projections incorporate the U.S. climate and socioeconomic projections. In turn, the landscape pattern projections are based on the land use projections (Brooks et al. 2020). Land use projections are strongly influenced by population and economic drivers; changes are more rapid and more extensive in futures of higher populations or more rapid economic growth (or both). Analyses that rely only on the land use or landscape

Figure 3-4. Characteristics differentiating the 2020 RPA Assessment scenarios. These characteristics are associated with the four underlying Representative Concentration Pathway (RCP) – Shared Socioeconomic Pathway (SSP) combinations.

RPA Scenario (RCP-SSP)	Global Temperature Rise	U.S. Population Growth	U.S. Economic Growth Rate	Bioenergy Demand	Energy Sector Focus	Global Energy Usage	International Trade Openness
LM Lower warming Moderate growth *RCP4.5-SSP1*	Lower	Medium	Medium-High	High	Renewables	Low	Medium
HL High warming Low growth *RCP8.5-SSP3*	High	Low	Low	Low	Fossil fuels	Medium	Low
HM High warming Moderate growth *RCP8.5-SSP2*	High	Medium	Medium	Medium	Mixed	Medium	Medium
HH High warming High growth *RCP8.5-SSP5*	High	High	High	High	Fossil fuels	High	High

Figure 3-5. Pathway for incorporation of global scenarios into RPA resource analyses. Global scenario projections are downscaled across the U.S. and either incorporated directly into RPA resource analysis or indirectly (through land use/landscape pattern projections). RPA resource analyses are examples and not intended to be an exhaustive list.



Source: Langner et al. 2020.

patterns incorporate the scenario variables indirectly, instead of directly modeling the effects of climate, population, etc. More information about the land use and landscape pattern projections are available in the Land Resources Chapter.

Additionally, some resources factor individual scenario storylines into their model-based assumptions. In the case of forest products, for example, in addition to the direct incorporation of scenario variables, the FOrest Resource Outlook Model (FOROM) of global trade also incorporates differences across scenarios in trade openness, technology change rates, production and consumption increases in wood-based bioenergy, and forest growth rate changes globally and domestically (Johnston et al. 2021).

Langner et al. (2020) provides a broad overview of the four 2020 RPA Assessment scenarios, focusing on how the climate and socioeconomic projections and qualitative aspects of each scenario may affect natural resource conditions and trends. The individual RPA Assessment resource chapters provide quantitative modeling results and a tangible picture of the plausible future of these resources absent intervention.

Conclusions

The RPA scenarios and their underlying assumptions provide a common and coherent framework for developing projections of natural resource impacts in the RPA Assessment. Built from the IPCC global Representative Concentration Pathways and Shared Socioeconomic Pathways, these national, downscaled scenarios address the legislative mandate for RPA resource projections. Because the RPA scenarios and climate models were selected to capture the range of plausible future climate and socioeconomic variability, the future of global and domestic natural resources can differ substantially across the four scenarios and 20 scenario-climate futures. Projecting the range of plausible futures for our natural resources allows for a better understanding of how the underlying climate and socioeconomic drivers of change can alter natural resource conditions and create challenges across the United States.

COVID-19 Implications on RPA Scenarios

The SARS-CoV2 virus and associated COVID-19 illness were first identified at the end of 2019, and the World Health Organization declared a global COVID-19 pandemic on March 11, 2020. The COVID-19 disease resulted in widespread public health and economy-wide impacts. Governments around the world implemented strict lockdown regulations to contain the spread of the virus, which, along with fears of contracting the COVID-19 illness, shrank economic activity to lows not experienced in decades and global emissions to levels not experienced since the early 2000s. While the economic contraction was worse than the 2007 to 2009 financial crisis and associated deep recession, growth returned more quickly due to fiscal support in a few large economies and the arrival of vaccines (International Monetary Fund 2021). The U.S. recession was the shortest on record, at 2 months, and U.S. real GDP exceeded its pre-COVID level by the second quarter of 2021 (USDC Bureau of Economic Analysis 2021). Emissions also rebounded rapidly alongside economic activity; global emissions in December 2020 were 2 percent higher than in December 2019 (IEA 2021).

Other COVID-19 related disruptions appear to be longer lasting. U.S. metropolitan areas have seen dense urban core populations shift into the outer suburbs, primarily an acceleration of pre-pandemic trends and likely due to the proliferation of remote work (Patino et al. 2021). Visitation to public lands increased significantly during the pandemic, with campgrounds seeing a nearly 40-percent increase in average nightly reservations in 2020, and visitation to undeveloped general forest settings rising by more than 50 percent when compared with 2015 (see the Outdoor Recreation Chapter). Global supply chains—already stressed before the pandemic due to trade tensions, particularly between the United States and China—have seen significant disruptions and delays due to the collapse and subsequent increase in consumer demand, leading to higher consumer prices for many commodities and at least temporary inflation. The U.S. labor market has also experienced disruptions, beginning with significant unemployment during lockdown (defined by stay-at-home orders and mass quarantines) and followed by labor shortages in certain industries. The U.S. forest products sector experienced supply and demand dynamics to extents not historically registered, behaviors all linked to COVID-19 directly (illness-related mill staffing shortages) or indirectly (see Forest Products Chapter).

More than 2 years into the pandemic, it is not known if or how these disruptions will influence long-term trends. For example, the effects on Federal lands visitation from other significant events in recent decades (e.g., the September 11, 2001, terrorist attacks, the 2007 to 2009 Great Financial Crisis, and spikes in gasoline prices) have been transitory. Alternatively, Natural Resources Institute Finland (UNECE 2021, Viitanen et al. 2020) predicts permanent effects on forest products markets, for example the demand for tissue and hygiene paper products as well as some packaging materials is predicted to permanently shift upward, due to an increased demand for products that support greater hygiene and increased e-commerce, respectively.

The RPA scenarios were developed before the arrival of the global pandemic and associated global recession. The RPA scenario development and associated downscaling process described in this chapter is a multi-year process, and downscaled projections are necessary inputs to subsequent resource modeling efforts. A potential concern is that the scenario-based modeling of alternative futures employed in the RPA Assessment would have been different had the full implications of COVID-19 been known. We assert that the currently understood implications of COVID-19 would not alter our RPA scenario development to any considerable degree. As described in this chapter, the RPA scenarios originate with global scenarios produced by the IPCC. The IPCC has not released revised global scenarios because of the pandemic. Any changes to the RPA scenarios would therefore be disconnected from global projections and assumptions, resulting in obstacles and inconsistencies in our globally linked analyses (for example, our analyses of forest product markets). In addition, the RPA scenarios were selected to encompass the range of plausible socioeconomic and climate futures, incorporating low- and high-warming futures alongside a wide variety of socioeconomic futures and climate models that cover the boundaries of existing climate projections. These scenarios would only be irrelevant if effects of COVID-19 permanently force the U.S. socioeconomic or climate futures beyond these boundaries; early data and patterns from the past year suggest that this is unlikely. The pandemic is more likely to change the magnitude of important model parameters than to change the direction of their effects, meaning that we are more likely to see temporary changes to or permanent intensifications of existing trends than wholescale upheavals of longstanding patterns and relationships.

As the pandemic progresses and hopefully ends, data will continue to be collected about consequences of COVID-19 that could have implications for renewable resources in the United States. We will continue to monitor new data and hope to assess potential long-term impacts in our next Assessment. Early data is analyzed for several resources in this Assessment—see COVID-19 sidebars in the Disturbance Chapter, the Forest Products Chapter, and the Outdoor Recreation Chapter for analyses of the effects of early stages of the pandemic on these resources.

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