Scenarios and Projections for the USDA Forest Service 2020 RPA Assessment

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The RPA Assessment

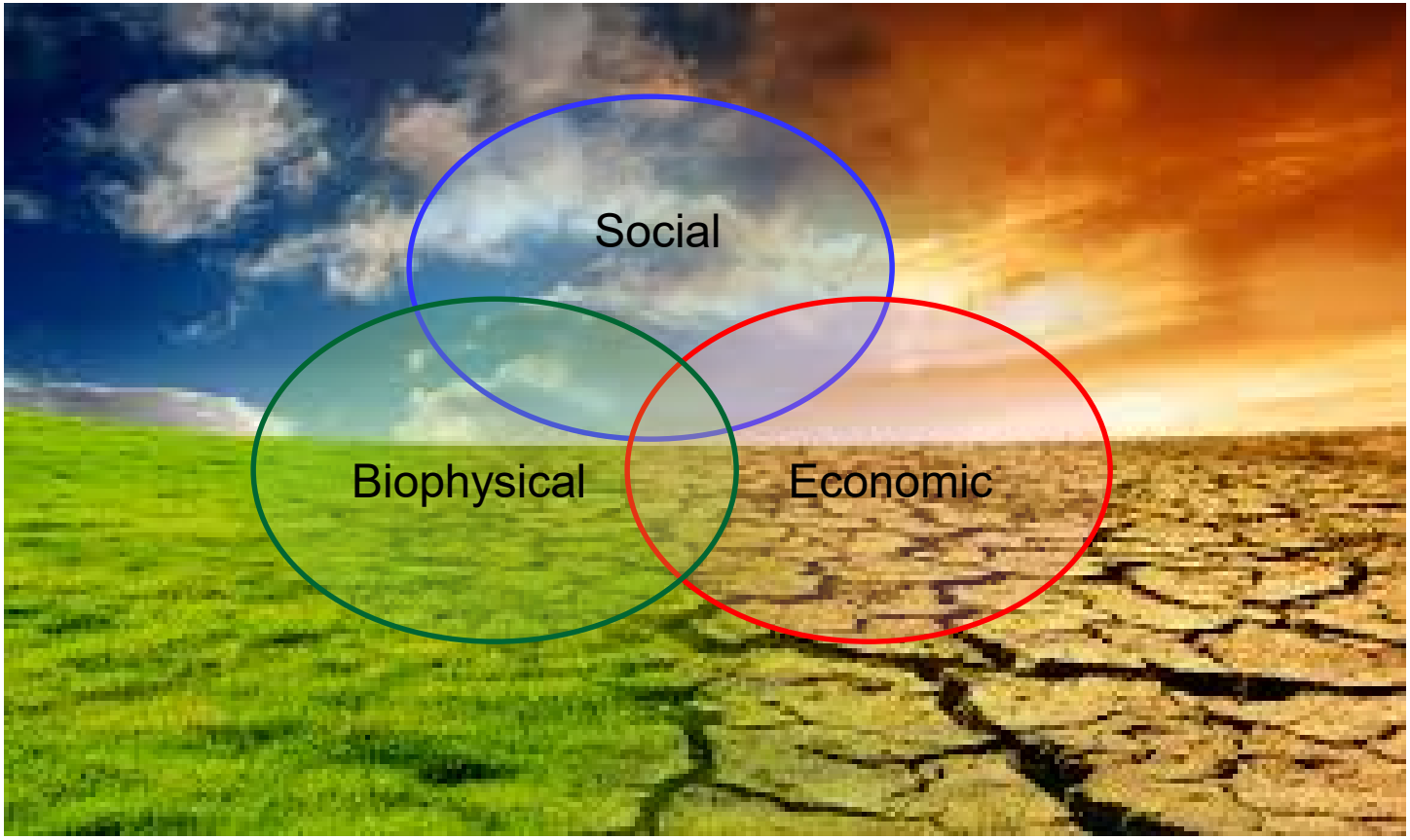
- The Forest and Rangeland Renewable Resources Planning Act of 1974 mandates a national report (RPA Assessment) on the conditions and trends of renewable resources **on all forest and rangelands** every ten years.
  - Land Resources
  - Forest Resources
  - Urban Forests
  - Forest Disturbance (fragmentation, drought, insect and disease trends)
  - Forest Products
  - Forest Carbon
  - Rangeland Resources
  - Water Resources
  - Wildlife, Fish, and Biodiversity
  - Outdoor Recreation

The RPA Assessment

- The Forest and Rangeland Renewable Resources Planning Act of 1974 mandates a national report (RPA Assessment) on the conditions and trends of renewable resources **on all forest and rangelands** every ten years.
- The RPA Assessment focuses on how the **interaction of economic, social, and biophysical factors** affects the productivity of forest and rangeland ecosystems and their ability to meet increasing demands for goods and services.
- The RPA Assessment provides a snapshot of current U.S. forest and rangeland conditions and trends; identifies drivers of change; and **projects 50 years into the future (2020-2070).**

Scenarios for the 2020 RPA

RPA Scenario-Climate Futures



Scenarios and Projections for the 2020 RPA Assessment

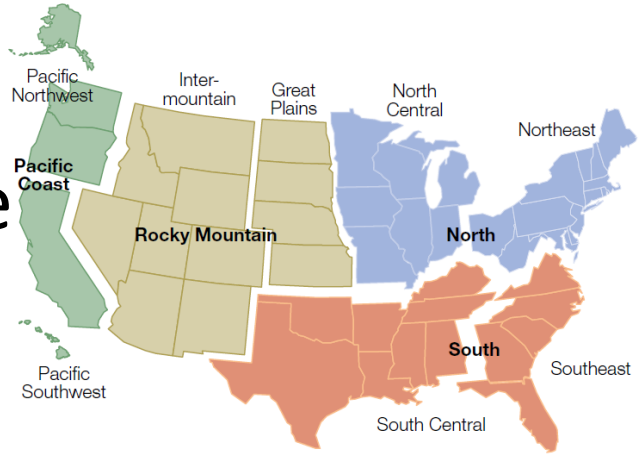
- Introduction to the RPA Assessment and the need for scenarios (Claire)
- Climate scenarios and projections (Linda)
- Socioeconomic scenarios and projections (Dave and Jeff)
- Integrated RPA scenarios (Claire)

Identifying Climate Scenarios and Projections for National Resource Assessments

Linda A. Joyce
Rocky Mountain Research Station
USDA Forest Service

How might Climate Change affect Natural Resources in the United States?

- Information needs
  - Different resources; different climate variables
- A Manageable Set
  - Scenarios, models, projections
- Selecting the projections
  - Results over time and space

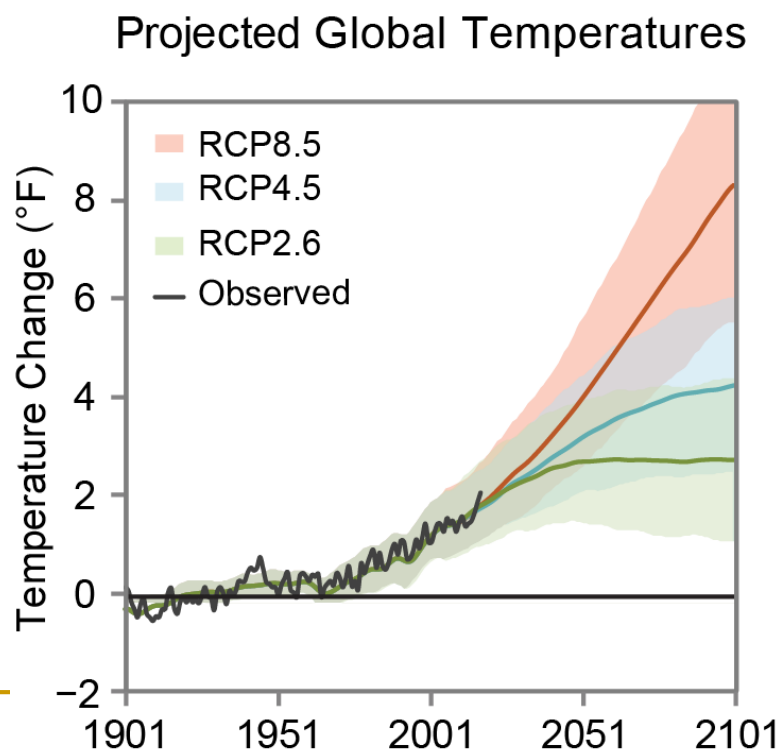


A manageable set

scenarios, models, projections

Representative Concentration Pathways - IPCC

RCP 2.6 RCP 4.5 RCP 6 RCP 8.5



Van Vuuren et al. 2011, USGCRP 2017

A manageable set

Climate Scenarios

RCP 2.6 RCP 4.5 RCP 6 RCP 8.5

Climate Models

At least 20 climate modeling institutions around the world

Climate Projections

More than one model each institutions

Plus -

Socio-Economic Scenarios

Climate Information Needed?

- min/max temperature, precipitation,
- solar radiation, min/max relative humidity, wind speed
- Time step – daily/monthly
- Spatial grain – as fine as possible

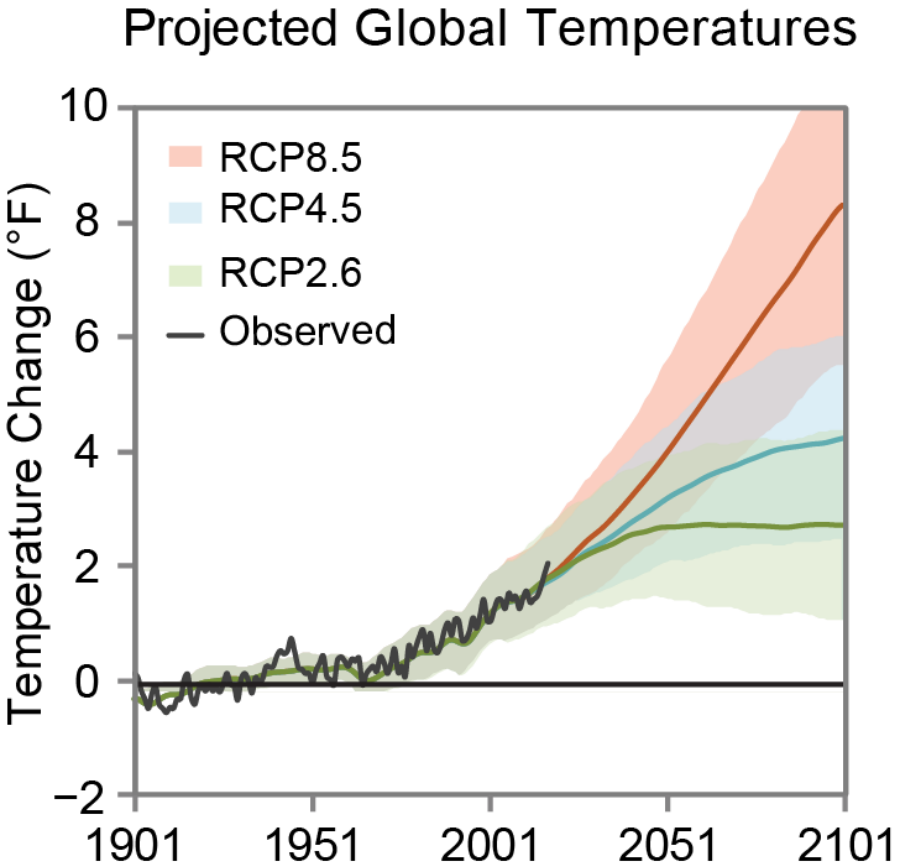
How many Futures?

- Scenarios used in the 5th IPCC assessment
  - 4 Representative Concentration Pathways

Decision:

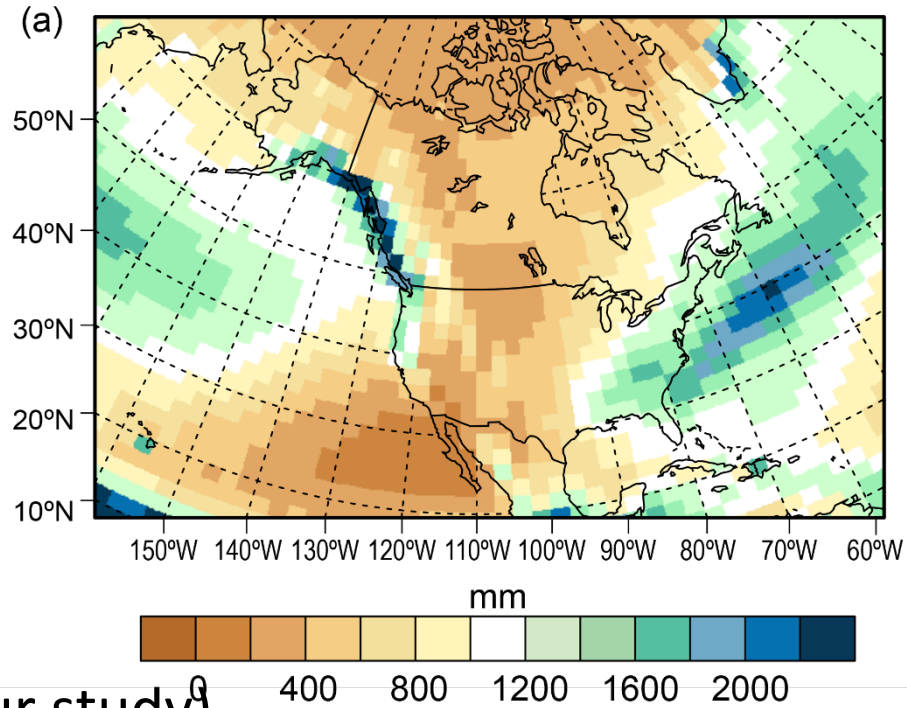
RCP 4.5 (mid)

RCP 8.5 (high)



Climate Model Output

- Availabl
  - NASA Ea (NEX-GDDP)
  - NASA Ea ojections (NEX-DCP30)
  - Bias Cor CMIP5)
  - Multivar IACAv2)
  - Localize able at the start of our study)



Annual average precipitation (in millimeters) for the historical period 1979–2008. Grid size 150 miles on a side (National Climate Assessment 2017)

Downscaled climate in RPA 2020

Multivariate Adaptive Constructed Analogs (MACAv2)

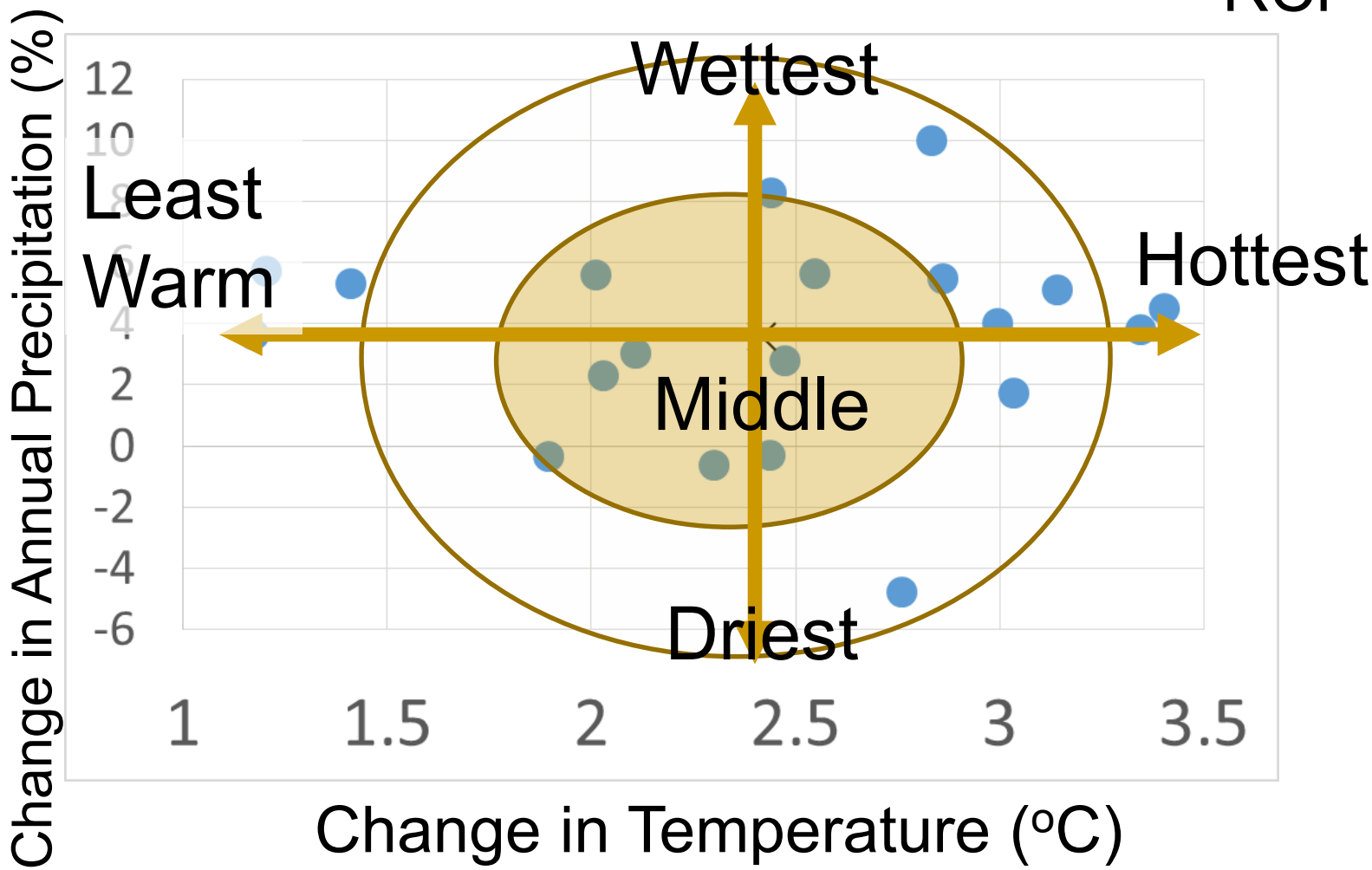
Developed by John Abatzoglou and colleagues, University of Idaho

Climate Variables we needed
Grid cell size – 4 km
20 climate models, several RCP scenarios
METDATA training data set

https://climate.northwestknowledge.net/MACA/index.php

How many Climate Projections?

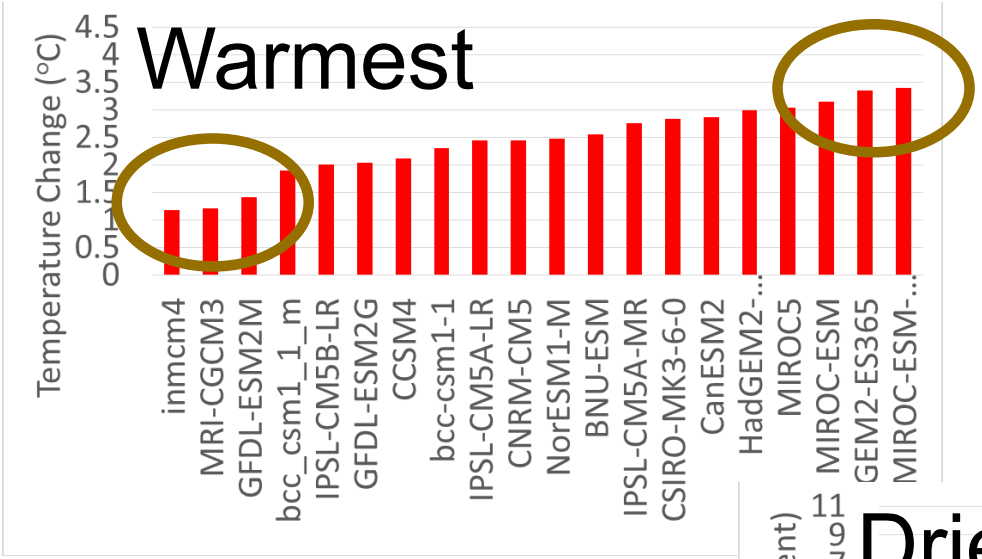
RCP 4.5

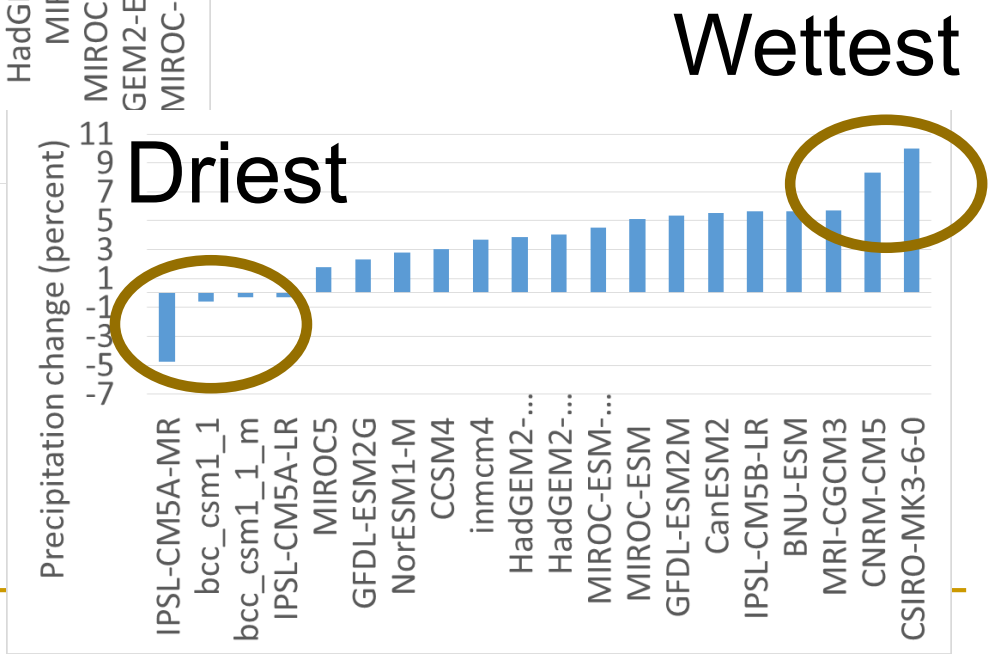


● - Projection X - Mean of 20 models

Historical (1971-2000), Future (2041-2070)

Change in Temperature and Precipitation at 2070 under RCP 4.5



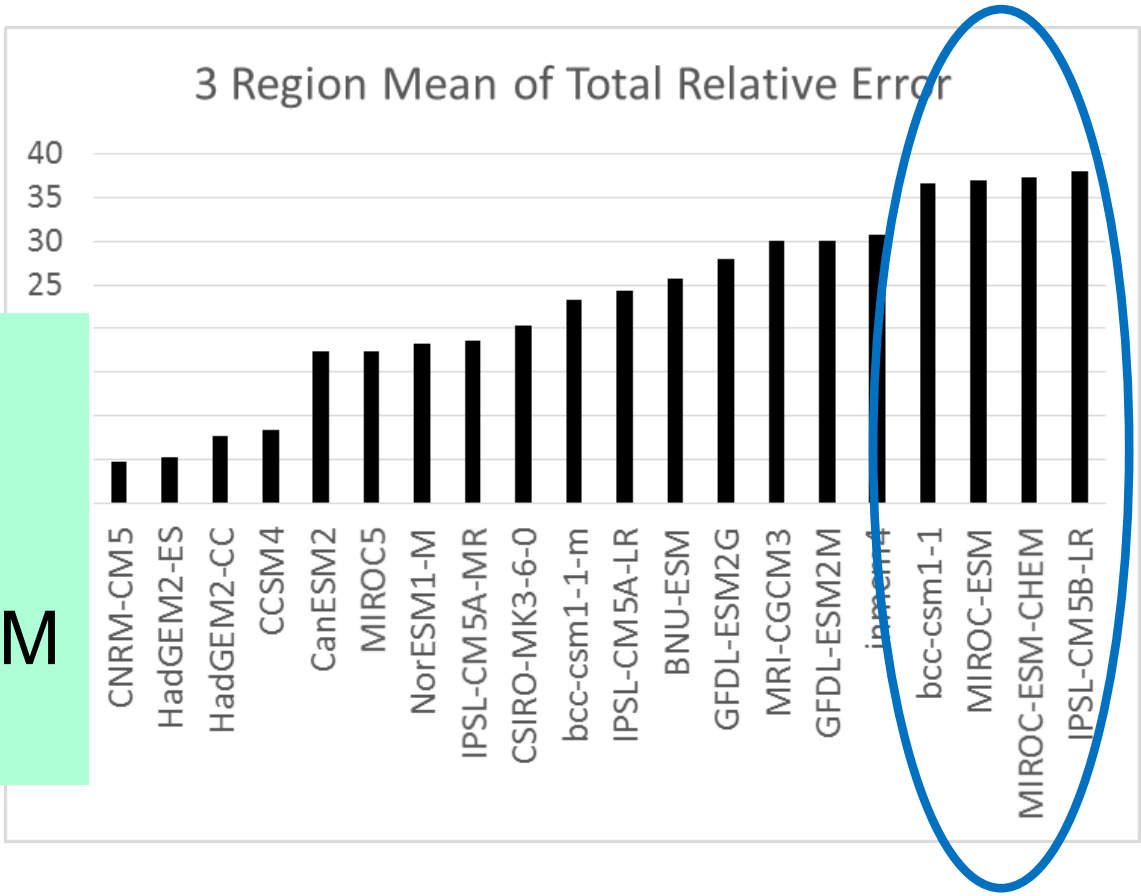


MACAv2METDATA, Historical period (1971-2000), Future period (2041-2070).

Ability of model to capture history

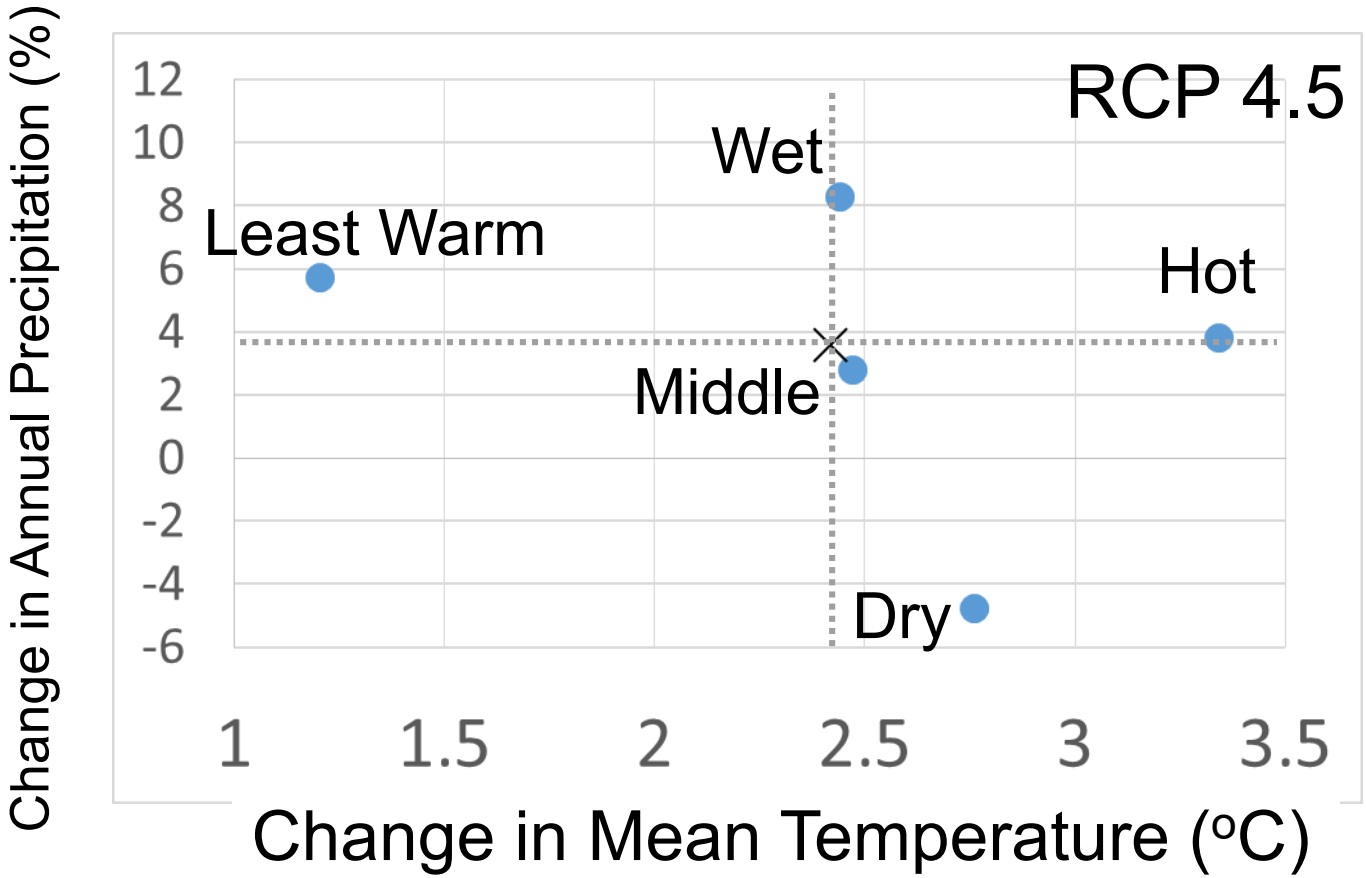
- Model evaluation by Rupp and others
- Focus on metrics

Drop 4 models
bcc-csm1-1
MIROC-ESM
MIROC-ESM-CHEM
IPSL-CM5B-LR



Rupp et al. 2013, Rupp 2016a, 2016b

Core Climate Models: RCP 4.5, RCP 8.5



Least Warm – MRI-CGCM3

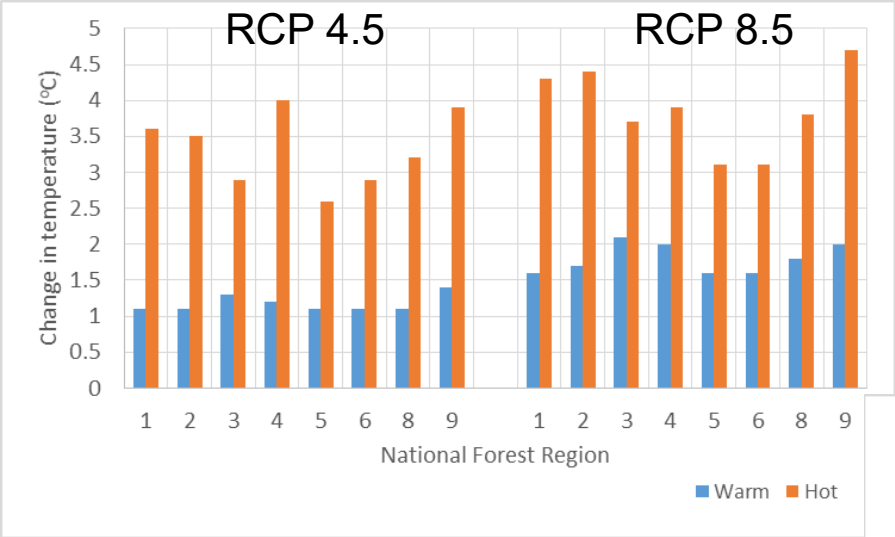
Dry – IPSL-CM5A-MR

Middle – NorESM1-M

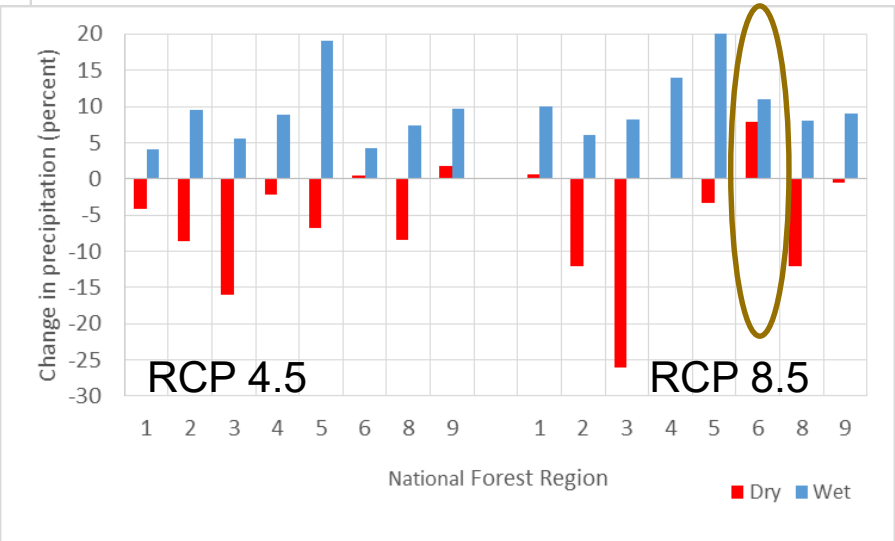
Hot – HadGEM2-ES

Wet – CNRM-CM3

Are core models also hot, least warm, wet, dry projections at a regional scale?



Hottest is always hotter than the Least Warm



Wettest is always wetter than Driest

National Forest Regions

Climate Data available - Forest Service Research Data Archive

RCP 4.5 and RCP 8.5 Projections

Core Models – HadGEM2-ES, MRI-CGCM3

CNRM-CM3, IPSL-CM5A-MR, NorESM1-M

Historical Observed Data – 1979-2015
Historical Modeled Data – 1950-2005
Projections – 2006-2100

Joyce and Coulson. (in review). Climate Scenarios and Projections for the 2020 RPA Assessment. RMRS Gen. Tech. Report.

Climate Data, FS Research Data Archive

https://www.fs.usda.gov/rds/archive/

Socioeconomic Projection Downscaling

Jeff Prestemon, Research Forester and Project Leader, Forest Service SRS

Dave Wear, formerly Senior Scientist with Forest Service SRS, currently Nonresident Senior Fellow, Resources for the Future

Downscaled Socioeconomic Pathways

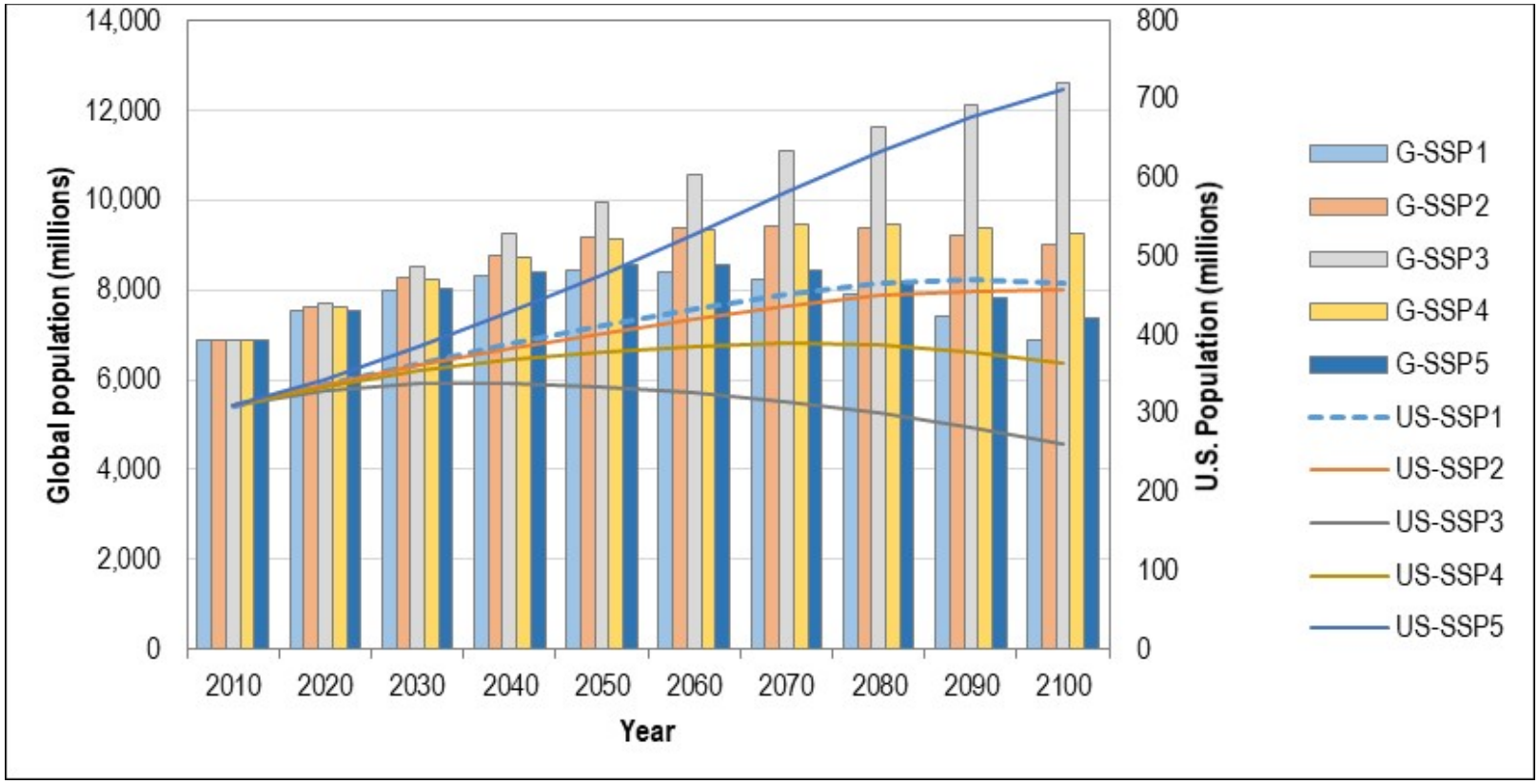
- **Problem**: Resource impact assessments require fine scale projections of both climate and socioeconomic futures… consistent with the pairing of RCP's and Shared Socioeconomic Pathways used for global analysis.
- **Objective**: develop county-level projections of population and income consistent with the national projections developed for global Shared Socioeconomic Pathways
- **Approach**: Use a spatially explicit economic growth framework to develop "coherent" forecasts of income and population quantity.

Shared Socioeconomic Pathways

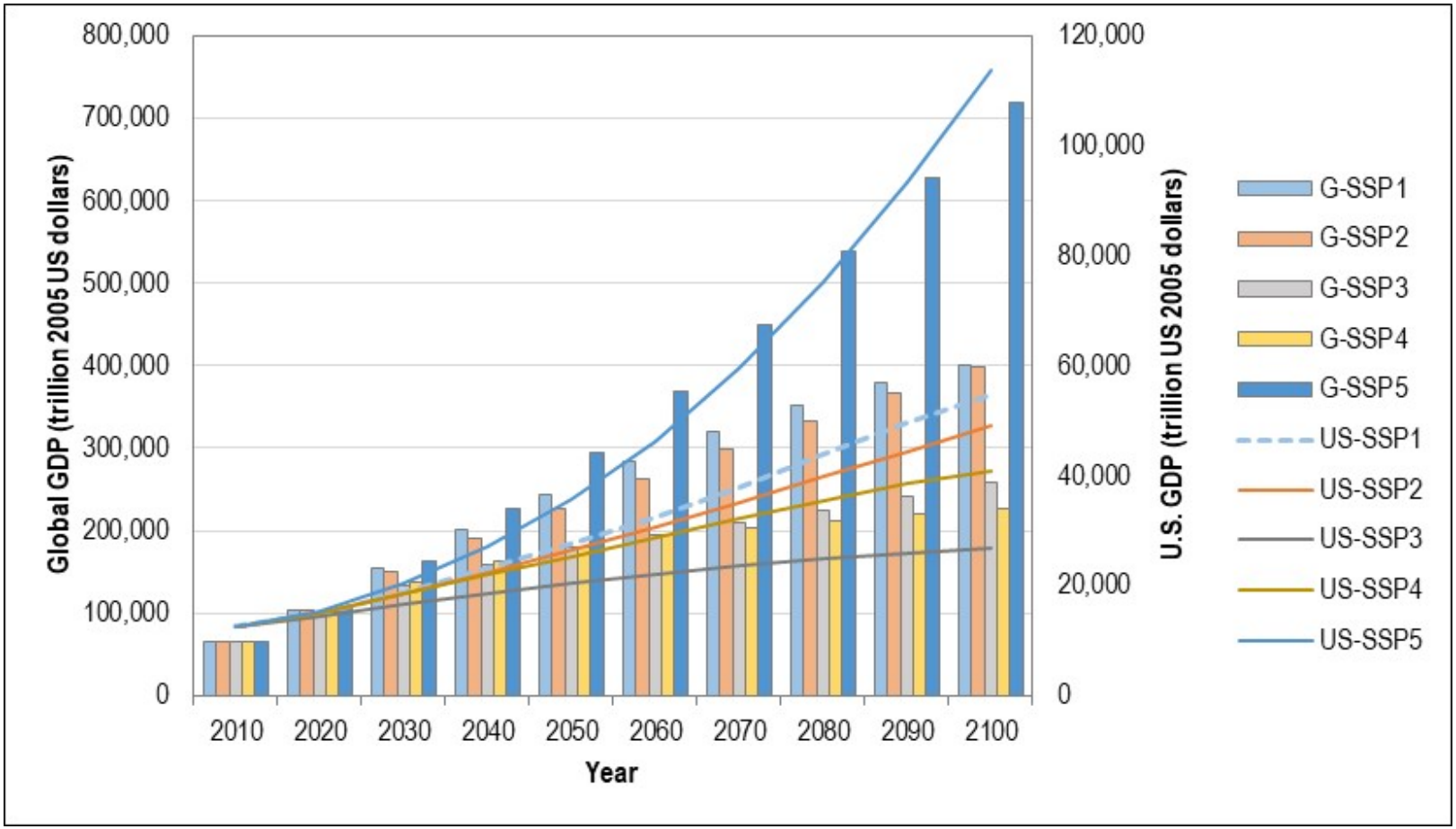
- Developed as adjuncts to IPCC Assessments
- Describe five different storylines of income, population, and other socioeconomic changes through 2100

Shared Socioeconomic Pathway	
1	Wealthy, Equal, emphasis on renewables, high US but low global population growth
2	Continuation of recent historical trends in population, income, trade policies, human migration patterns, technology change
3	Unequal and low economic growth, high global but low US population growth, low migration, trade restrictions
4	Segmented world--rich get richer, poor stay the same (NOT USED IN RPA)
5	Wealthy, somewhat equal world, low global but high US population, fossil fuels emphasized, more migration, free trade

SSPs: Population



SSPs: Income


800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Global GDP (trillion 2005 US dollars)
120,000
100,000
80,000
60,000
40,000
20,000
0
U.S. GDP (trillion US 2005 dollars)
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
G-SSP1
G-SSP2
G-SSP3
G-SSP4
G-SSP5
US-SSP1
US-SSP2
US-SSP3
US-SSP4
US-SSP5

Spatial economic growth framework for U.S. counties

- **Premise**: income and population change are interrelated
  - Wage-driven labor migration: Population tends to move from areas of lower scarcity (wages) to areas of higher scarcity (wages)…
  - Leading to *income-convergence,* i.e., reduction in spatial variation of per capita income.
  - Consistent with nation-level economic growth models behind SSP estimates
- **Approach**: Statistical model of population/income change at the county level
  - Joint modeling of change in population number and per capita income at the county level
  - Also accounts for spatial growth effects (contagion)
  - Develops and ensemble of models and model averaging for projections

Details-Spatial economic growth framework

- Data: five-year time step
- Statistical model: Fixed-factor panel model

$$Y_t = \delta Y_{t-1} + \rho \mathbf{W} Y_{t-1} + \propto_{iN} + \mathbf{X}_t \beta + \mathbf{W} X_t \theta + \mu + \varepsilon_{iN} + u_t$$

$$u_t = \lambda W u_t + \varepsilon_t$$

- Spatial lags (W)
- Temporal lags (t-1)
- Fixed factors: location and time
- Time fixed factor (u_t)as a total growth rate shifter

Model matching

- Estimate statistical models
- Define model ensemble—model averaging
  - Select models based on out-of-sample performance
- Match SSP output pairs (population and income)
  - Setting the time fixed factor to simulate national totals from SSP
  - Preserving empirical temporal and spatial spread relationships

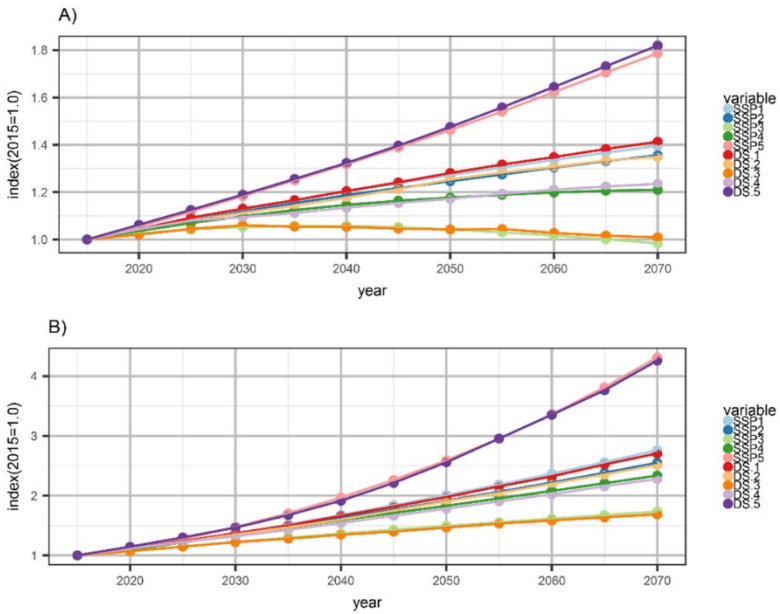
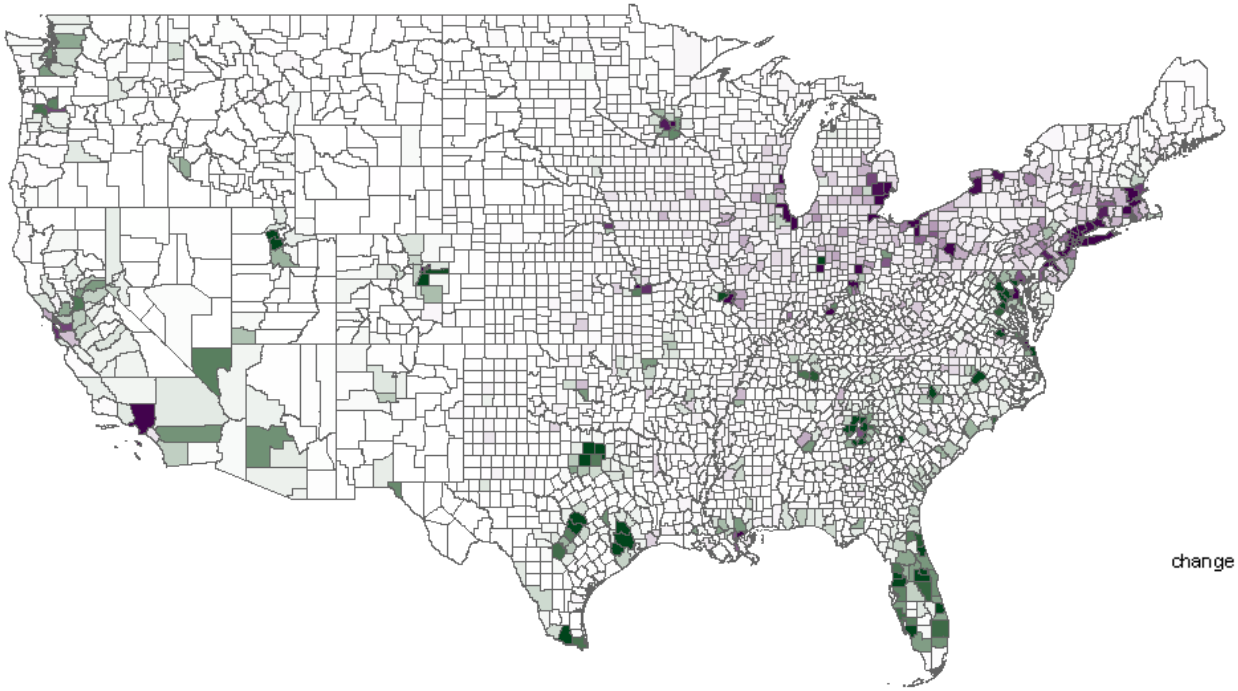


Fig 1. Population and GDP Projections.

Projections of indices of (A) US population, and (B) US Gross Domestic Product (in constant2005 dollars) projected for five Shared Socioeconomic Pathways indexed to a value of 1 in 2015.

County-level population projections (SSP3)

SSP3

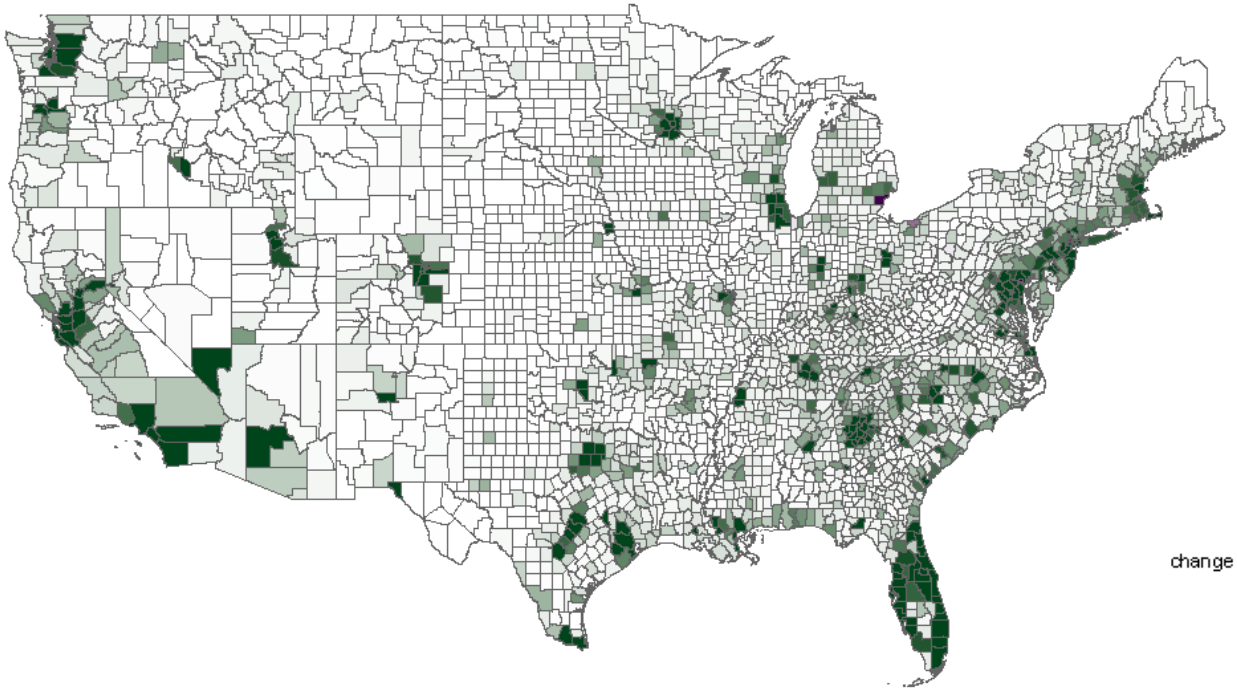


Population projections.

Projected change in population density (people per square mile, ppsm) between 2010 and 2070 Shared Socioeconomic Pathways: SSP3 (low growth).

County-level population projections (SSP2)

SSP2

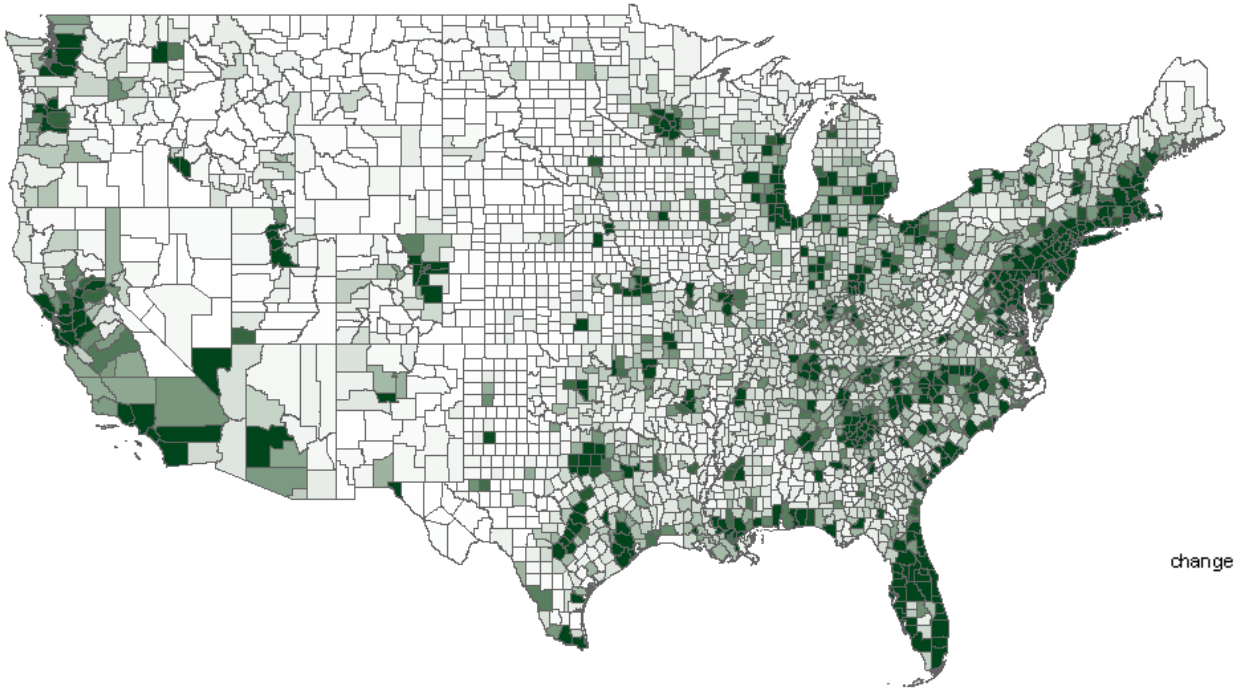


Population projections.

Projected change in population density (people per square mile, ppsm) between 2010 and 2070 Shared Socioeconomic Pathways: SSP2 (medium growth).

County-level population projections (SSP5)

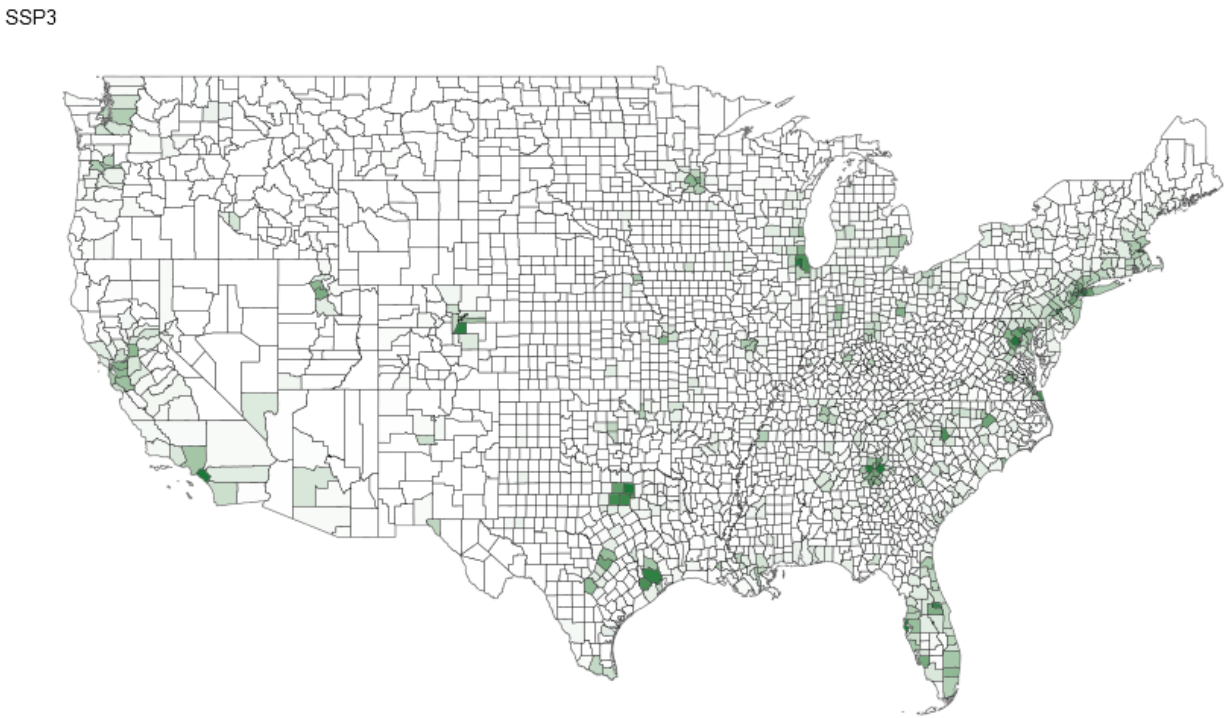
SSP5



Population projections.

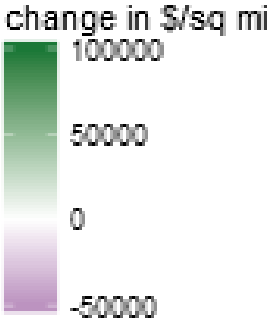
Projected change in population density (people per square mile, ppsm) between 2010 and 2070 Shared Socioeconomic Pathways: SSP5 (high growth).

County-level income projections (SSP3)

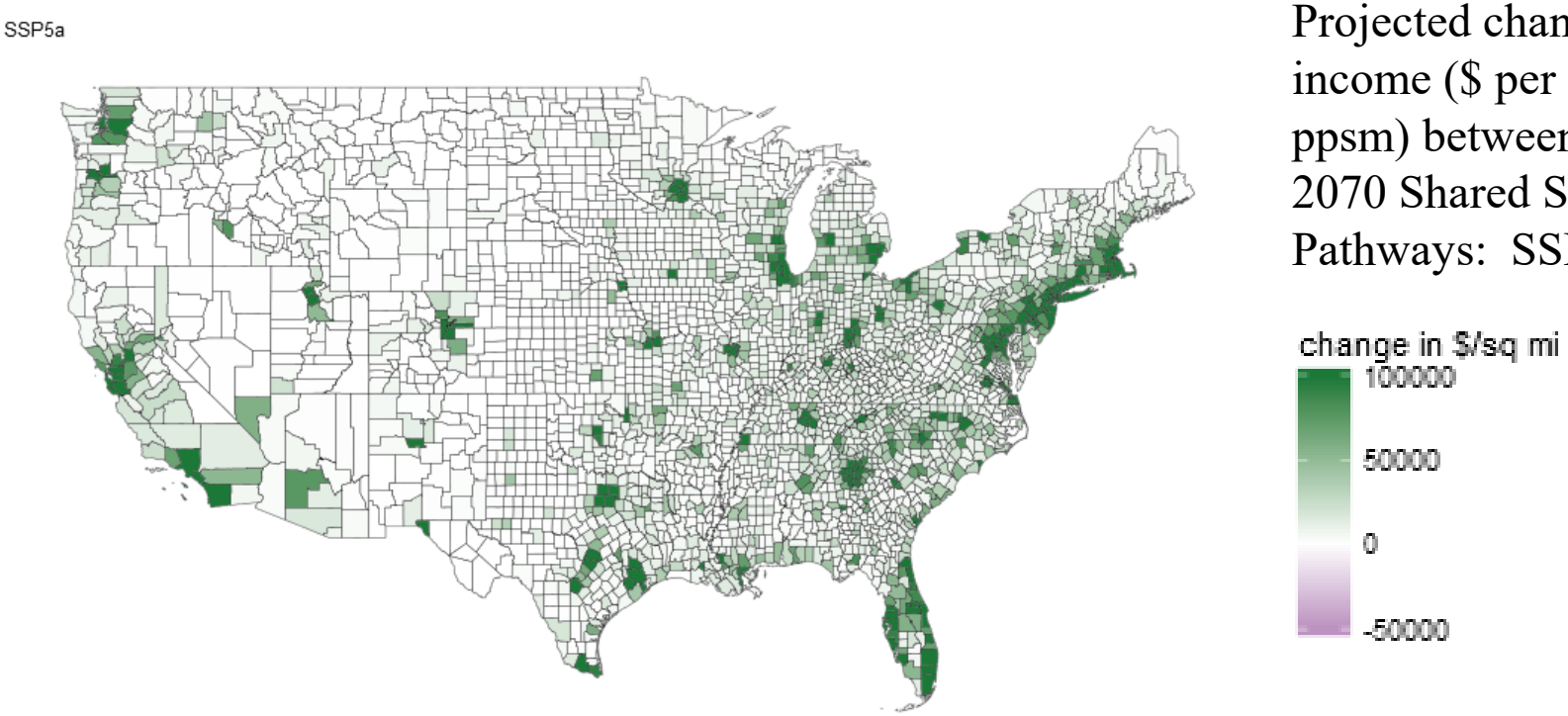


Income projections.

Projected change in personal income ($ per square mile, ppsm) between 2010 and 2070 Shared Socioeconomic Pathways: SSP3.



County-level income projections (SSP5)



Income projections.

Projected change in personal income ($ per square mile, ppsm) between 2010 and 2070 Shared Socioeconomic Pathways: SSP5.

Convergence behavior?

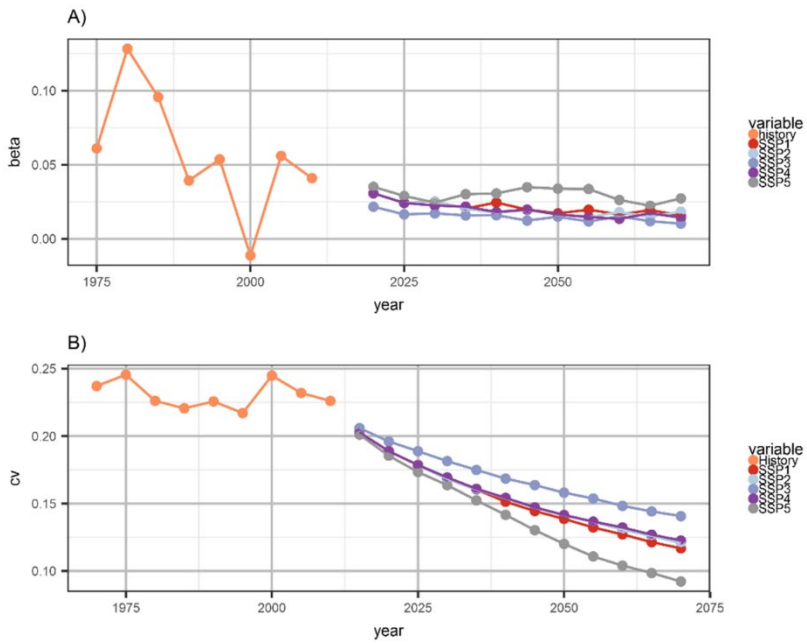


Fig 5. Convergence measures.

(A) Beta measures of convergence, defined as the rate of personal income convergence, and (B) sigma measures of convergence, measured as the coefficient of variation of per capita personal income across counties.

- With exception of one period, historical change in per capita income is consistent with convergence at the county level
- Projections of county level change in income and population reflect a continued convergence dynamic
- Consistent with wage-driven labor migration

Conclusions

Findings

- Statistical spatial models of population and economic growth have strong explanatory power
- Projection model based on ensemble of specifications yields strong out-of-sample performance and…
- Provides downscaled projections of SSPs that are consistent with historical patterns of growth

Caveats

- SSPs derive from complex narratives regarding future global economic and policy conditions
- Models provide only downscaled quantities of income and population resulting from the SSPs
- Keep in mind other elements of the SSPs when applying projections to impact analysis.

2020 RPA Assessment Scenarios

integrating socioeconomic and climate scenarios
to make resource projections…

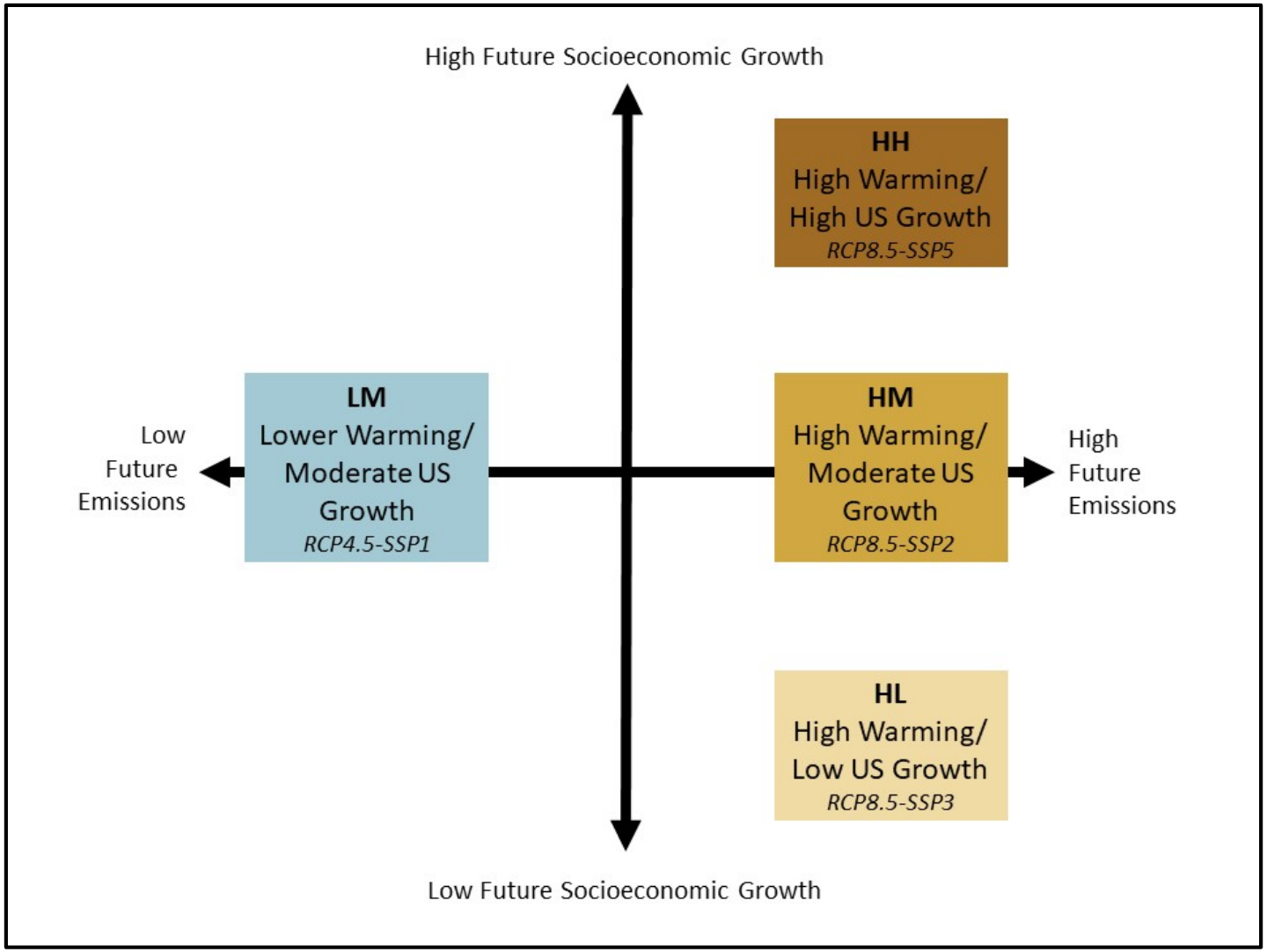
Scenarios in the 2020 RPA

- Climate scenarios (RCPs)
  - RPA selected RCPs 4.5 and 8.5 (5 different GCMs)
    - Climate projections include min/max temperature, precipitation, solar radiation, min/max relative humidity, wind speed (~4k grid)
- Socioeconomic scenarios (SSPs)
  - RPA selected SSPs 1, 2, 3, and 5
    - Population and personal income projections (by county)

2020 RPA Assessment Core Scenarios

Scenario Trends	Scenario LM	Scenario HL	Scenario HM	Scenario HH
Global warming and U.S. socioeconomic growth	Lower warming/ moderate US growth	High warming/Low US growth	High warming/ Moderate US growth	High warming/High US growth
U.S. Population Growth	Medium	Low	Medium	High
U.S. Economic Growth	Medium	Low	Medium	High
Global Population Growth	Low	High	Medium	Low
Global Economic Growth	Medium	Low	Medium	High
GHG Emissions	Lower	High	High	High
Global RCP/SSP Linkage	RCP 4.5/SSP1	RCP 8.5/SSP3	RCP 8.5/SSP2	RCP 8.5/SSP5

2020 RPA Assessment Core Scenarios



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U.S. Economic Growth	Medium	Low	Medium	High
Global Population Growth	Low	High	Medium	Low
Global Economic Growth	Medium	Low	Medium	High
GHG Emissions	Lower	High	High	High
Global RCP/SSP Linkage	RCP 4.5/SSP1	RCP 8.5/SSP3	RCP 8.5/SSP2	RCP 8.5/SSP5
	x5 climate models = 5 scenario/climate futures	x5 climate models = 5 scenario/climate futures	x5 climate models = 5 scenario/climate futures	x5 climate models = 5 scenario/climate futures

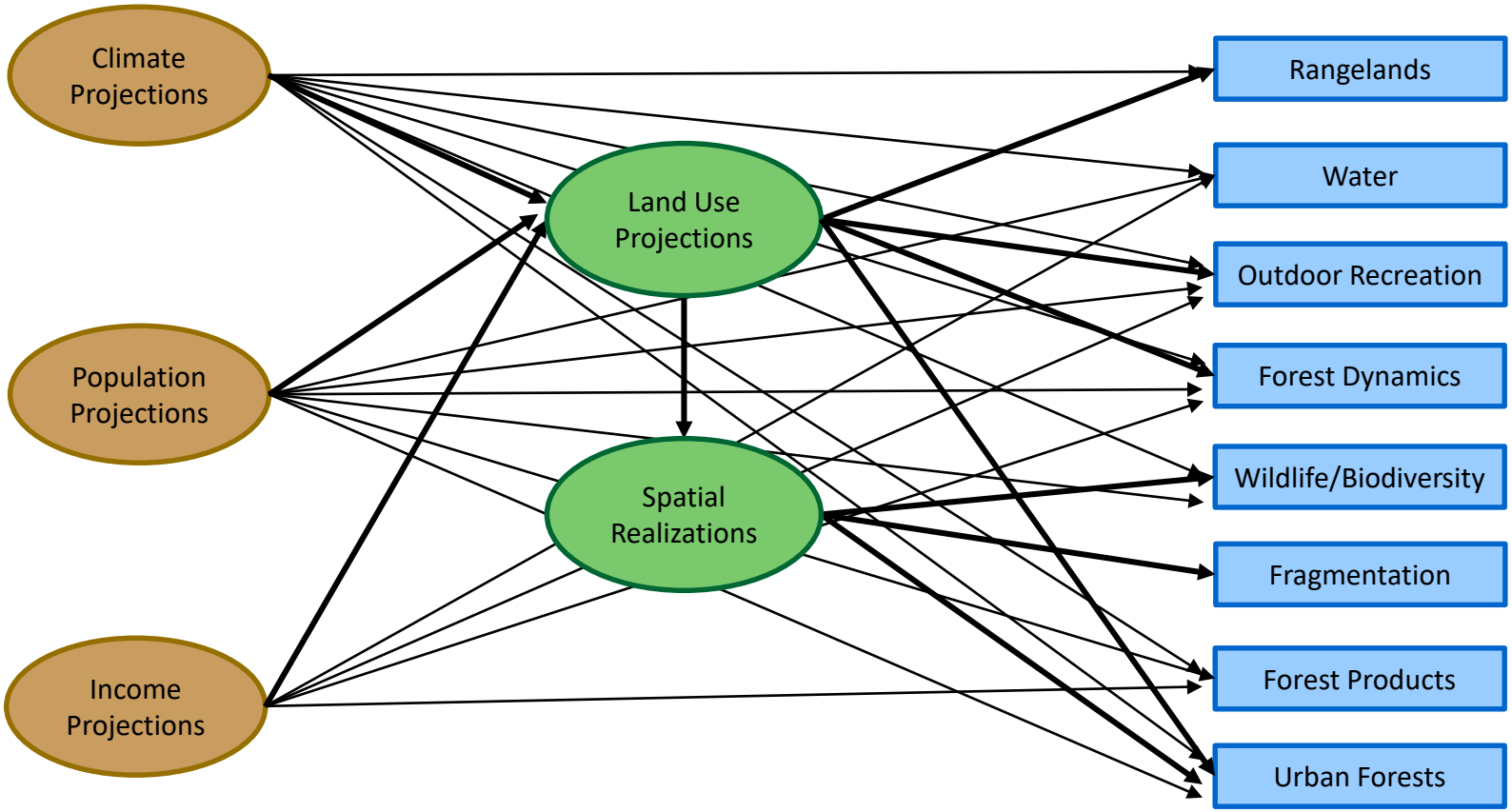
= 20 scenario/climate futures

Resources Evaluated

The RPA Assessment includes analyses of the following resources:

- Land Resources
- Forest Resources
- Urban Forests
- Forest Disturbance (fragmentation, drought, insect and disease trends)
- Forest Products
- Forest Carbon
- Rangeland Resources
- Water Resources
- Wildlife, Fish, and Biodiversity
- Outdoor Recreation

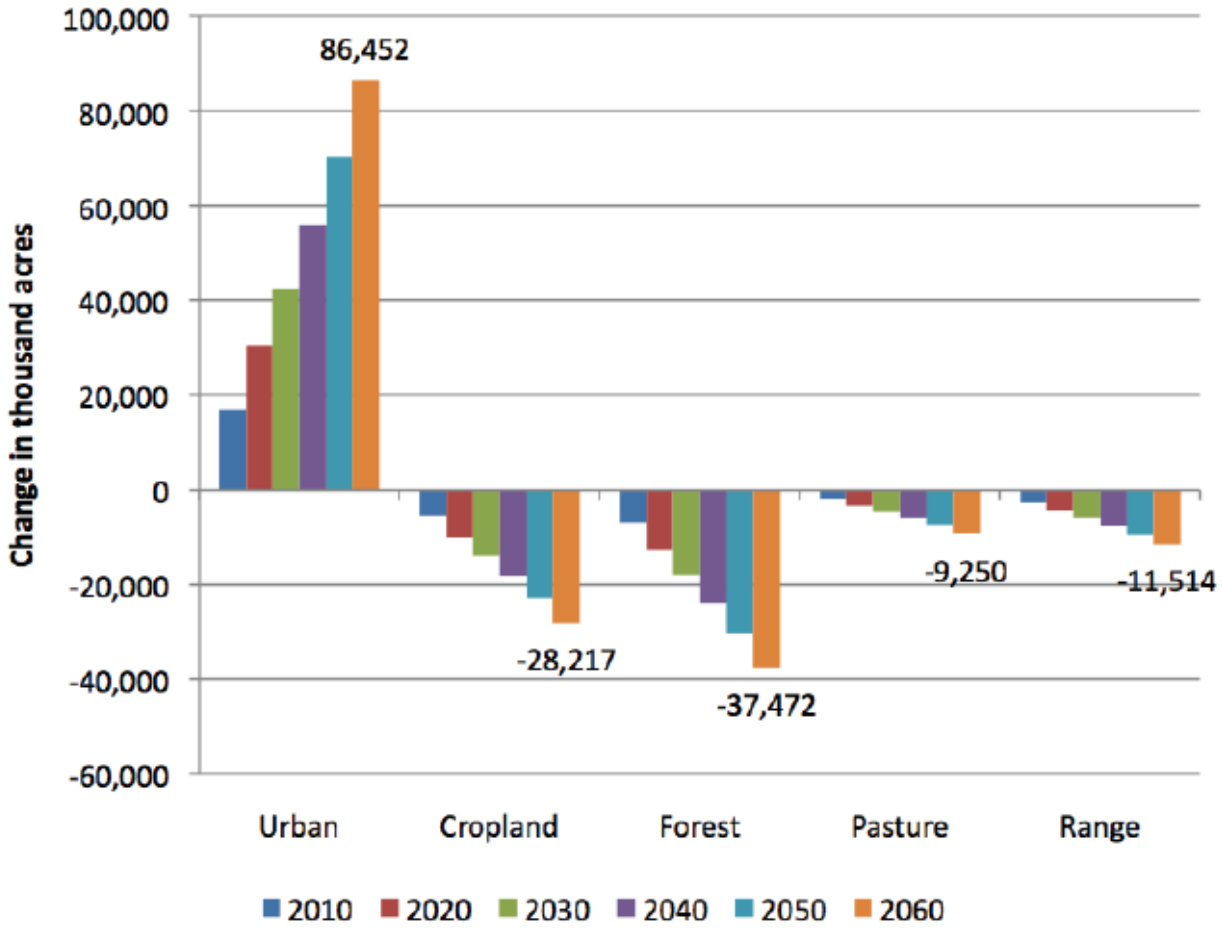
Integrated Projections



Example RPA Resource Projections

taken from the 2010 RPA Assessment cycle
(*2010 RPA Assessment* and *Update to the 2010 RPA Assessment*)

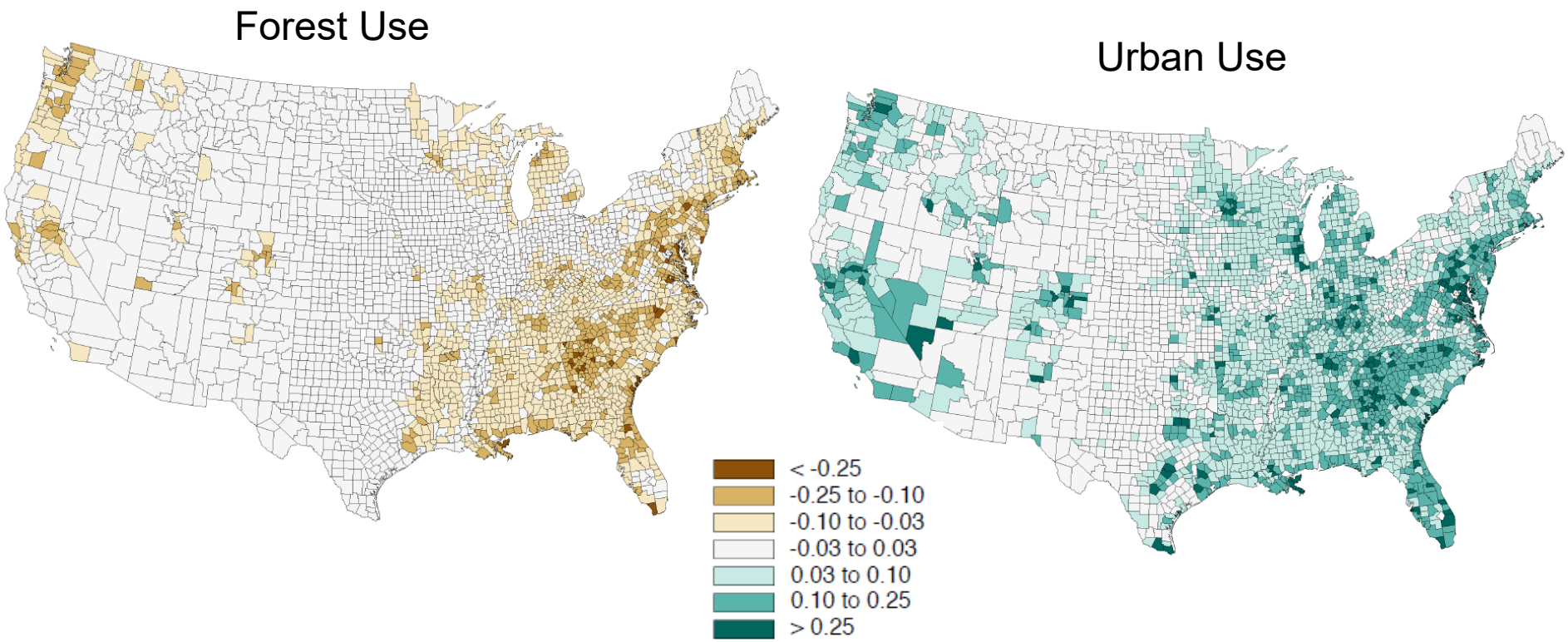
RPA Resource Projections
(2010 land use)



Forecasted change in the areas of major nonfederal land uses 2010-2060 (2010 RPA Assessment).

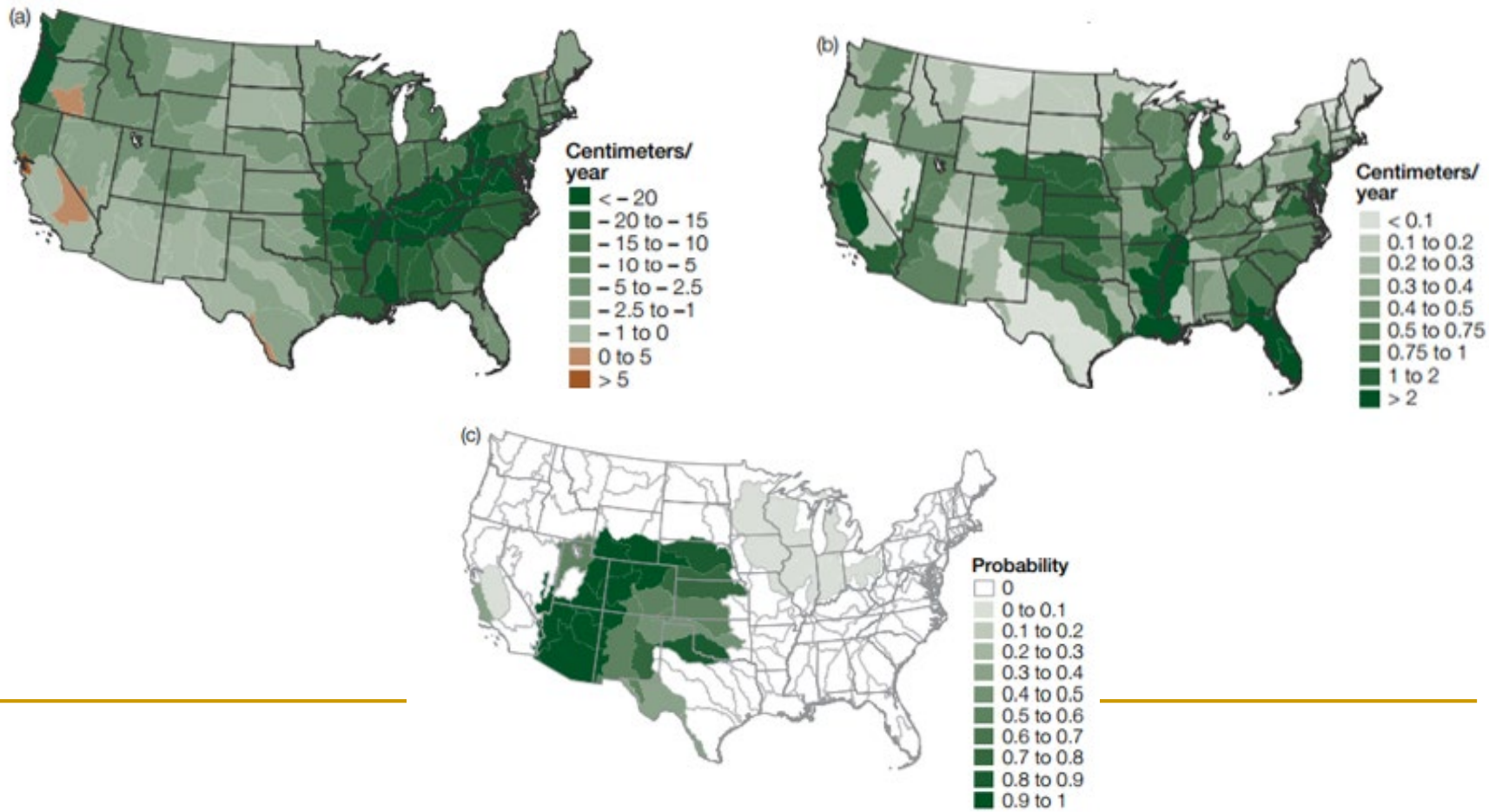
RPA Resource Projections
(2010 land use)

Forecasted change in proportion of county in forest and urban land use
1997-2060 (A1B Scenario)



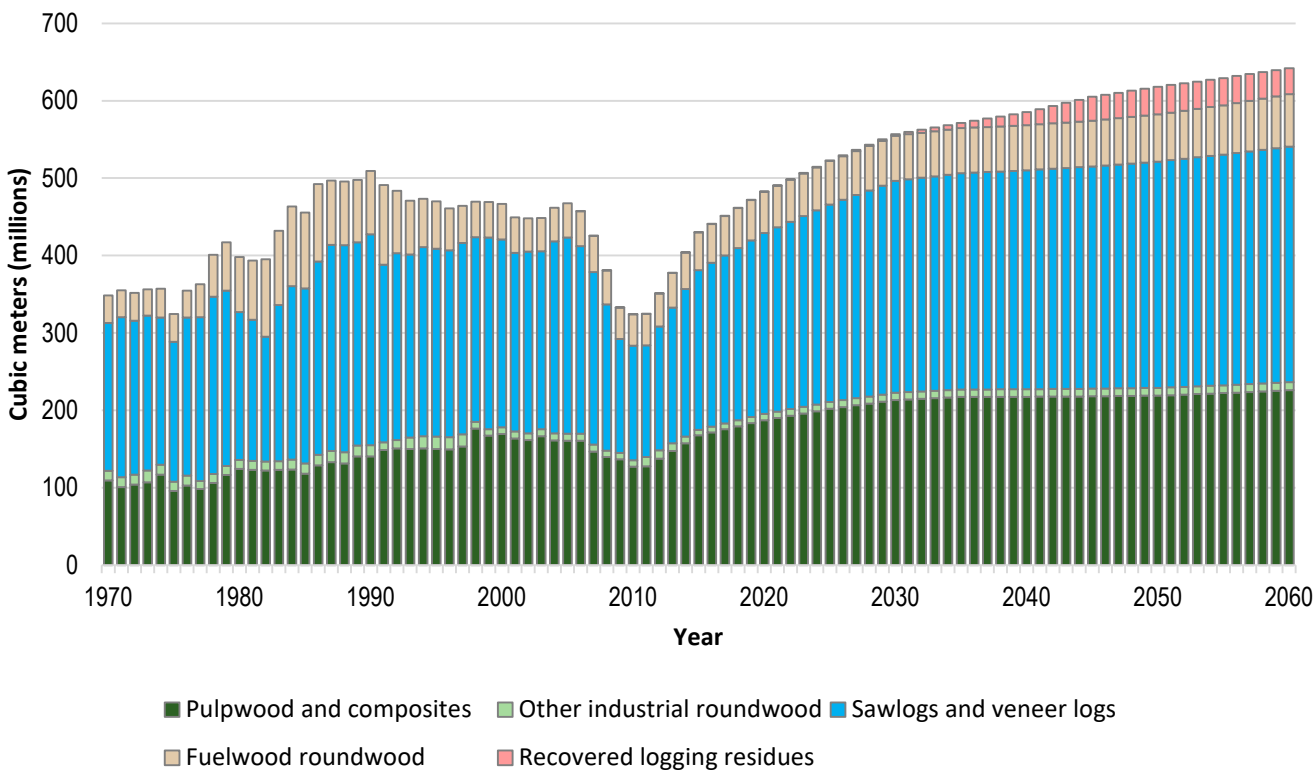
RPA Resource Projections
(2015 water availability)

Projected change per unit area in 2060 water: (a) yield, (b) demand, and (c) change in the probability of shortage (2015-2060).



RPA Resource Projections
(2015 forest products)

U.S. historical annual timber harvest volumes, 1980 to 2011; projection of timber harvest and recovered logging residues, 2012-2060

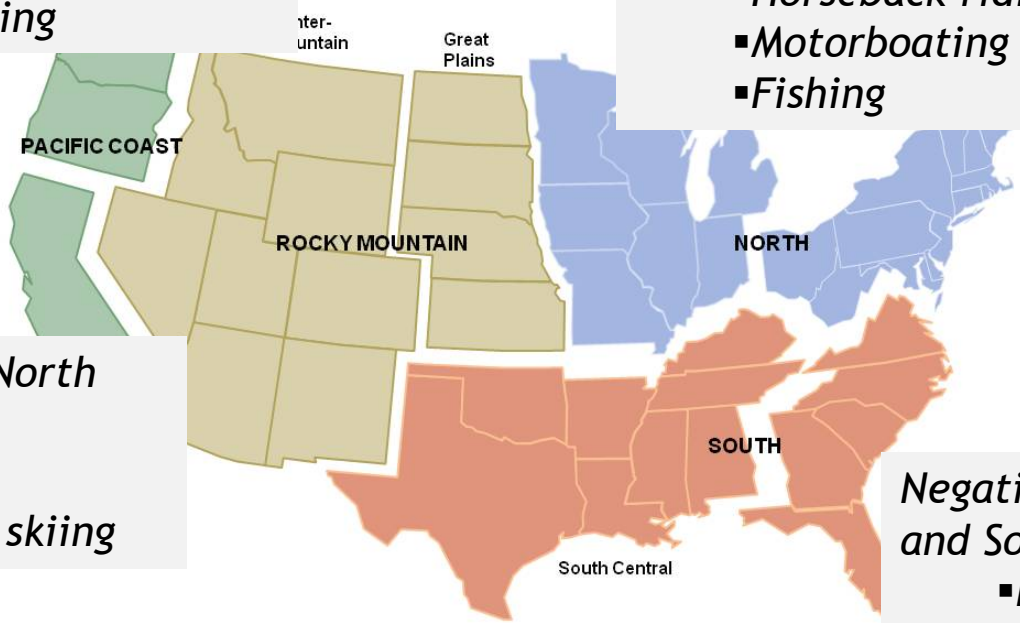


RPA Resource Projections
(2015 outdoor recreation participation)

Climate change will influence participation in outdoor recreation opportunities (annual days per participant more than participation rates)

Negative effects - North and Pacific Coast Regions:
- *Snowmobiling*

Positive effects - North Region:
- *Horseback riding on trails*
- *Motorboating*
- *Fishing*



Negative effects - North and RM Regions:
- *Hunting*
- *Undeveloped skiing*

Negative effects – North and South Regions
- *Floating*

Publications and Data

- **Socioeconomic scenarios and projections**
  - Wear, David N.; Prestemon, Jeffrey P. 2019. Spatiotemporal downscaling of global population and income scenarios for the United States. PLOS ONE. 14(7): e0219242-. https://doi.org/10.1371/journal.pone.0219242
  - Wear, David N.; Prestemon, Jeffrey P. 2019. Socioeconomic data for Forest Service 2020 RPA Assessment. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2019-0041
- **Climate scenarios and projections**
  - Joyce, LA, Coulson, D. (in review) Climate scenarios and projections for the 2020 RPA Assessment. Gen. Tech. Rpt. RMRS-GTR-XXX. Fort Collins, CO: USDA Forest Service Rocky Mountain Research Station. XX p.
  - Joyce, Linda A.; Abatzoglou, John T.; Coulson, David P. 2018. Climate data for RPA 2020 Assessment: MACAv2 (METDATA) historical modeled (1950-2005) and future (2006-2099) projections for the conterminous United States at the 1/24 degree grid scale. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2018-0014

RPA website: https://www.fs.fed.us/research/rpa/

Publications and Data

- **RPA Assessment documentation**
  - Langner, L.L.; Joyce, L.A.; Wear, D.N.; Prestemon, J.P.; Coulson, D.; O'Dea, C.B. (in review). 2020 RPA Assessment scenarios. Gen. Tech. Rep. RMRS-GTR-XX. Fort Collins, CO: U.S. Department of Agriculture Forest Service Rocky Mountain Research Station. XX p.
  - Nelson, M.D.; Riitters, K.H.; Coulston, J.W.; Domke, G.M.; Greenfield, E.J.; Langner, L.L.; Nowak, D.J.; O'Dea, C.B.; Oswalt, S.N.; Reeves, M.C.; Wear, D.N. (in review). Defining the United States Land Base: A Technical Document Supporting the USDA Forest Service 2020 RPA Assessment. Gen. Tech. Rpt. NRS-GTR-XX. Newtown Square, PA: U.S. Department of Agriculture Forest Service Northern Research Station. XX p.
  - Oswalt, Sonja N.; Smith, W. Brad; Miles, Patrick D.; Pugh, Scott A., coords. 2019. Forest Resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA Assessment. Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/WO-GTR-97
  - RPA website (https://www.fs.fed.us/research/rpa/) hosts citations for supporting publications and data, webinar recordings, and previous RPA Assessment cycles.

RPA Assessment Lead Scientists

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- Curt Flather (Wildlife, Fish, Biodiversity) Rocky Mountain Research Station
- Linda Joyce (Climate Change) Rocky Mountain Research Station
- Pat Miles (FIA RPA Database) Northern Research Station
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- Sonja Oswalt (FIA), Southern Research Station
- Jeff Prestemon (Forest Products Markets and Trade) Southern Research Station
- Matt Reeves (Range) Rocky Mountain Research Station
- Kurt Riitters (Landscape Pattern) Southern Research Station
- Travis Warziniack (Water) Rocky Mountain Research Station
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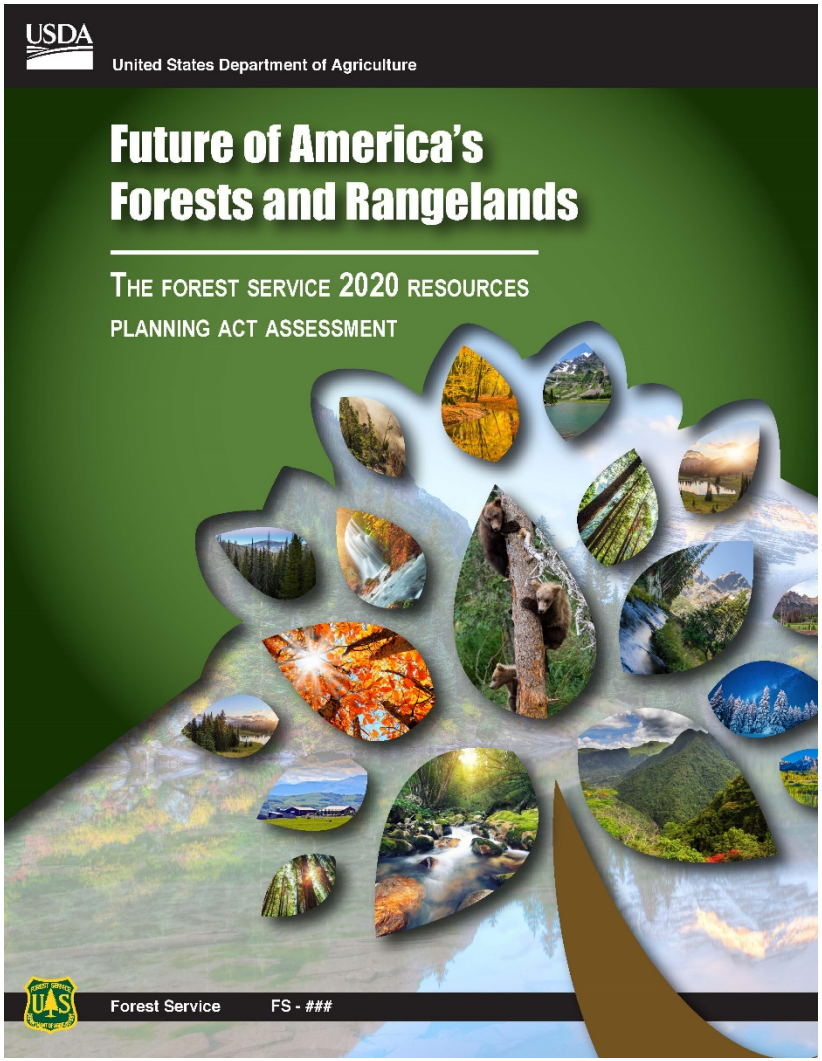

Thank you!

Please see our website: https://www.fs.fed.us/research/rpa/

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