Forest carbon under increasing product demand and land use change in the US South

Jesse D. Henderson
Robert C. Abt
Karen L. Abt

Motivation

- Revisit[1] wood pellet “sustainability” (e.g. impacts on forest carbon).
- Old findings relied on Wear’s land use model but required *ad hoc* sensitivities of forest types to timber prices (rents) → **<u>create a new land use model</u>**

[1]Abt, K. L., Abt, R. C., & Galik, C. (2012). Effect of Bioenergy Demands and Supply Response on Markets, Carbon, and Land Use. *Forest Science*, *58*(5), 523–539. https://doi.org/10.5849/forsci.11-055

Land Use Model (land shares)

Variables [1]

- Land Shares (FIA)
- Pine plantation rents
- Population density
- Income per capita

[2]

- Survey Unit Data

→ Elasticities

Land share (y), survey unit (i), land use (k), time (t), parameters (Beta), explanatory variables (X)

$$\ln\left(\frac{y_{ikt}}{y_{iKt}}\right) = \beta_k X_{it} + \varepsilon_{ikt} \text{ for } k = 1, \ldots\ldots, K-1$$

- See [3] for details about the model.

[1] Fisher, M. (2020). *Land Use and Forest Type Change in the U.S. South* [North Carolina State University]. https://repository.lib.ncsu.edu/handle/1840.20/38199

[2] Kaya, E. T. (2021). *Essays on Land Use, Environment and Policy* [North Carolina State University]. https://repository.lib.ncsu.edu/handle/1840.20/38746

[3] Nagubadi, R. V., & Zhang, D. (2005). Determinants of Timberland Use by Ownership and Forest Type in Alabama and Georgia. *Journal of Agricultural and Applied Economics*, *37*(1), 173–186. https://doi.org/10.1017/s1074070800007185

Land Use Model

Embedding the land use model within the forest sector model.

$$\log\left(\frac{AG}{DV}\right) = B_0 + B_1 \log(Rent) + B_2 \log(Pop) + B_3 \log(Inc) + dummies$$

$$\log\left(\frac{AG}{DV}\right) = \boldsymbol{C}_0 + B_1 \log(Rent_0 * Rent_{index}) + B_2 \log(Pop_0 * Pop_{Index}) + B_3 \log(Inc_0 * Inc_{index})$$

$$\log\left(\frac{AG}{DV}\right) = \boldsymbol{D}_0 + B_1 \log(Rent_{index}) + B_2 \log(Pop_{Index}) + B_3 \log(Inc_{index})$$

$$\frac{AG}{DV} = e^{D_0}\left(e^{\log(R)}\right)^{B_1}\left(e^{\log(P)}\right)^{B_2}\left(e^{\log(I)}\right)^{B_3} = e^{D_0} R^{B_1} P^{B_2} I^{B_3} = DV * \beta_{AGt} R^{B_{i1}}$$

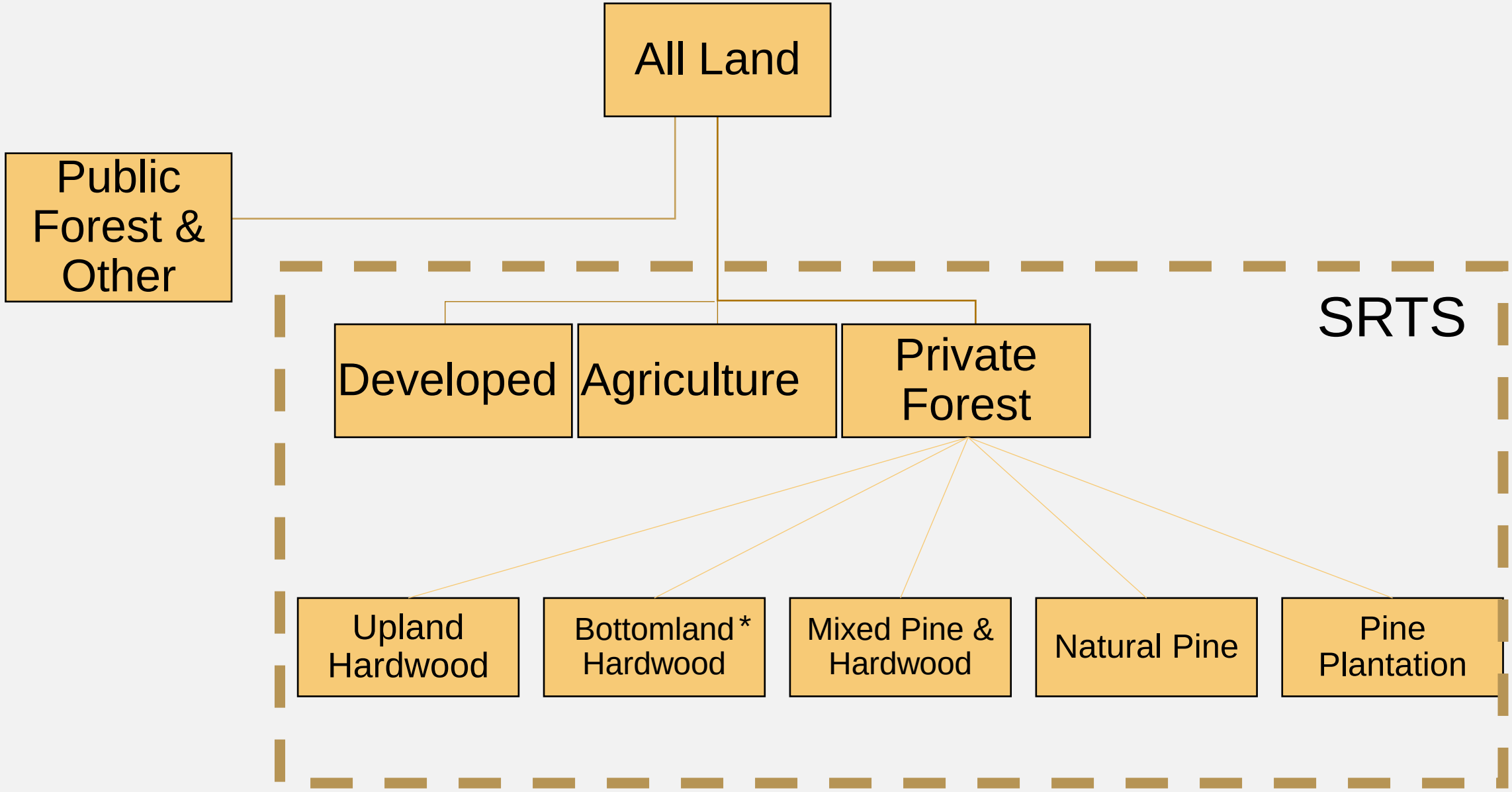
In General:

$$LandUse_i = DV * \beta_{it} R^{B_{i1}}$$

Ag, development, and 5 forest types

$$AG + DV + PP + NP + OP + UH + BH = 1$$

$$DV = \frac{1}{\left(1 + \sum_i \beta_{it} R^{B_1}\right)}$$


All Land
Public Forest & Other
SRTS
Developed
Agriculture
Private Forest
Upland Hardwood
Bottomland* Hardwood
Mixed Pine & Hardwood
Natural Pine
Pine Plantation

Population and Income Projections

- Projection for population, income per capita [1] are summarized at the survey unit level.
- Given elasticities from the land use model and forecasts from [2], I tabulate the β_{it} noted in the previous slide by Shared Socioeconomic Pathway (SSP)
- In this presentation we use SSP2

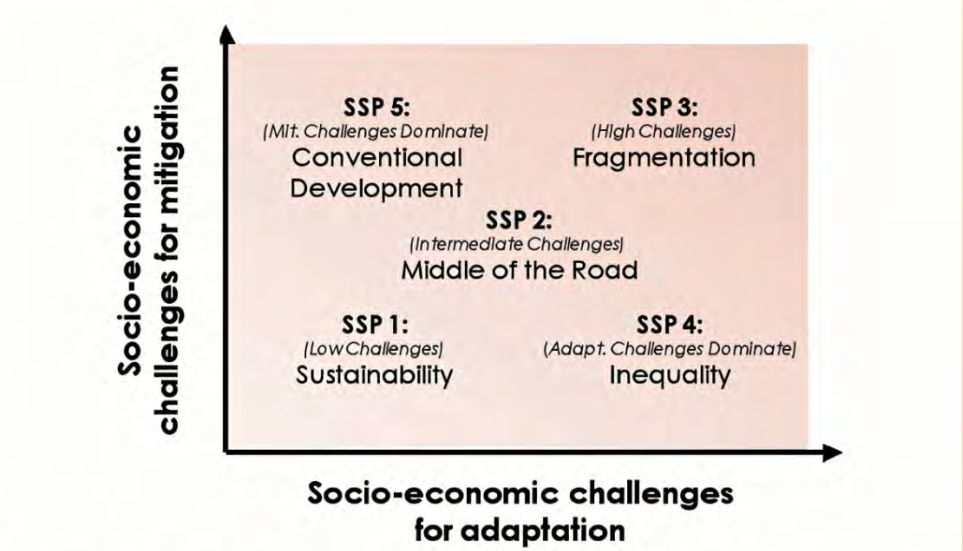


Figure 1. The Shared Socio-economic Pathways (SSPs) of the new IPCC-guided scenario set. Taken from O'Neill et al. (2012).

[1] Wear, D. N., & Prestemon, J. P. (2019). Spatiotemporal downscaling of global population and income scenarios for the United States. *PLoS ONE*, *14*(7), 1–19. https://doi.org/10.1371/journal.pone.0219242

Refocusing on some questions

- Based on the empirical model, can higher pine rents halt development? Overall, development tends to win, but pine plantations are sensitive to pine rents, and estimated parameters lead to tradeoffs between forest types and agriculture.
- What are the market and forest carbon impacts from the combination of factors?

Model Setup

- Wanting to capture:
  - In the long term: land use change due to population/income changes influences forest area.
  - In the short term: announcements for new wood-consuming mills in the US South – pellets and sawmills.
- Key Dynamics
  - pulp/pellet sourcing – sawmill residue or harvest?
  - Shared Socioeconomic pathways
- Couple these events within the Sub-Regional Timber Supply model to gauge the range of forest market responses. (price, removals, area, carbon)

Model Setup

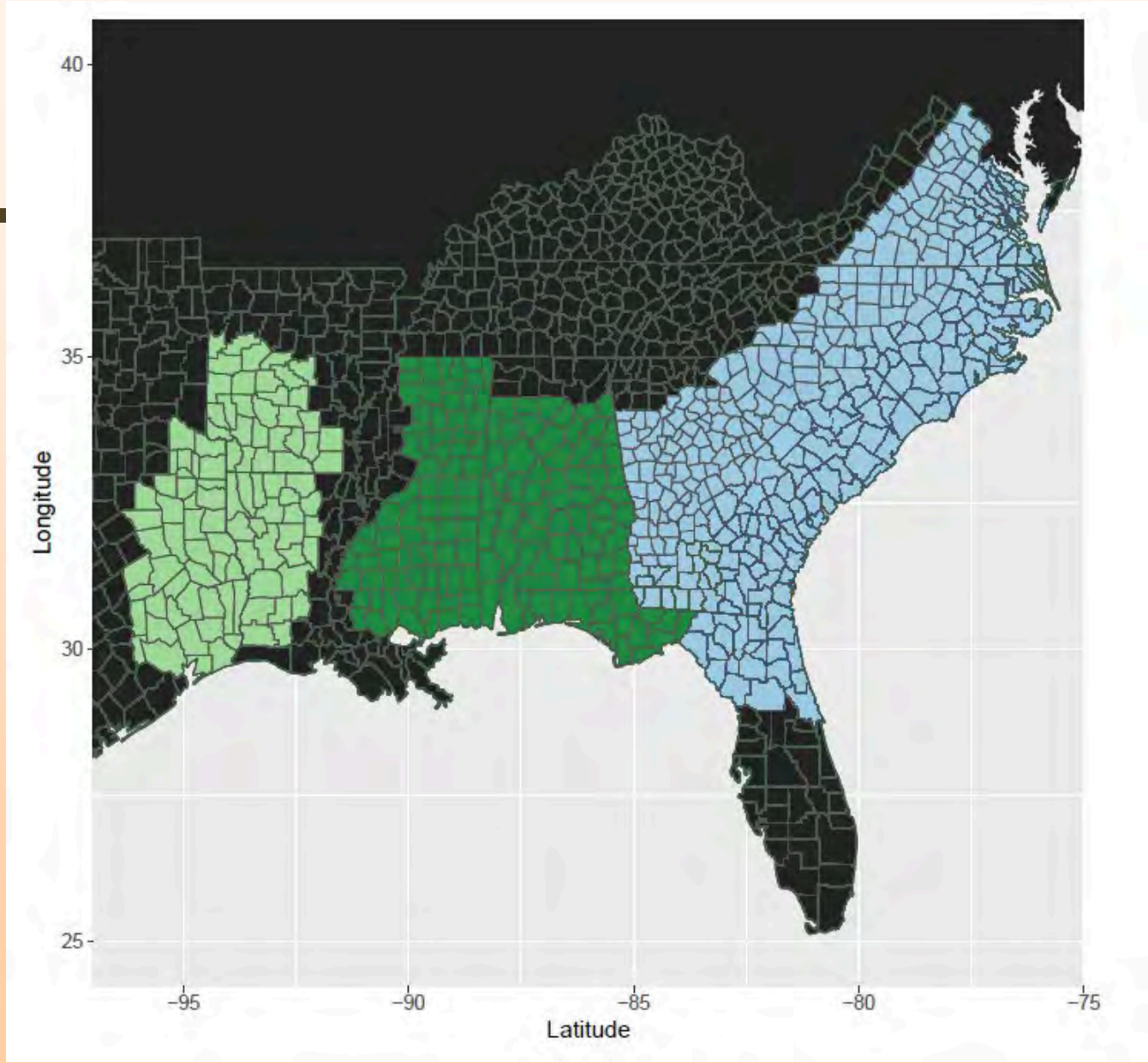
Demand

Abbr.	Pine Pulpwood	Pine Sawtimber
LL	Low	Low
LH	Low	High
HL	High	Low
HH	High	High

Demand based on announced capacity until 2030 (high), and 10% less by 2030 (low)

Three regions:
Atlantic (ATL; blue)
East Gulf (EGF; dark green)
West Gulf (WGF; light green)

Pine sawtimber mill residuals [2 cases]:
new capacity generates 25% sawmill residue vs. 45%



Demand

sawmill capacities are announced in MMBF

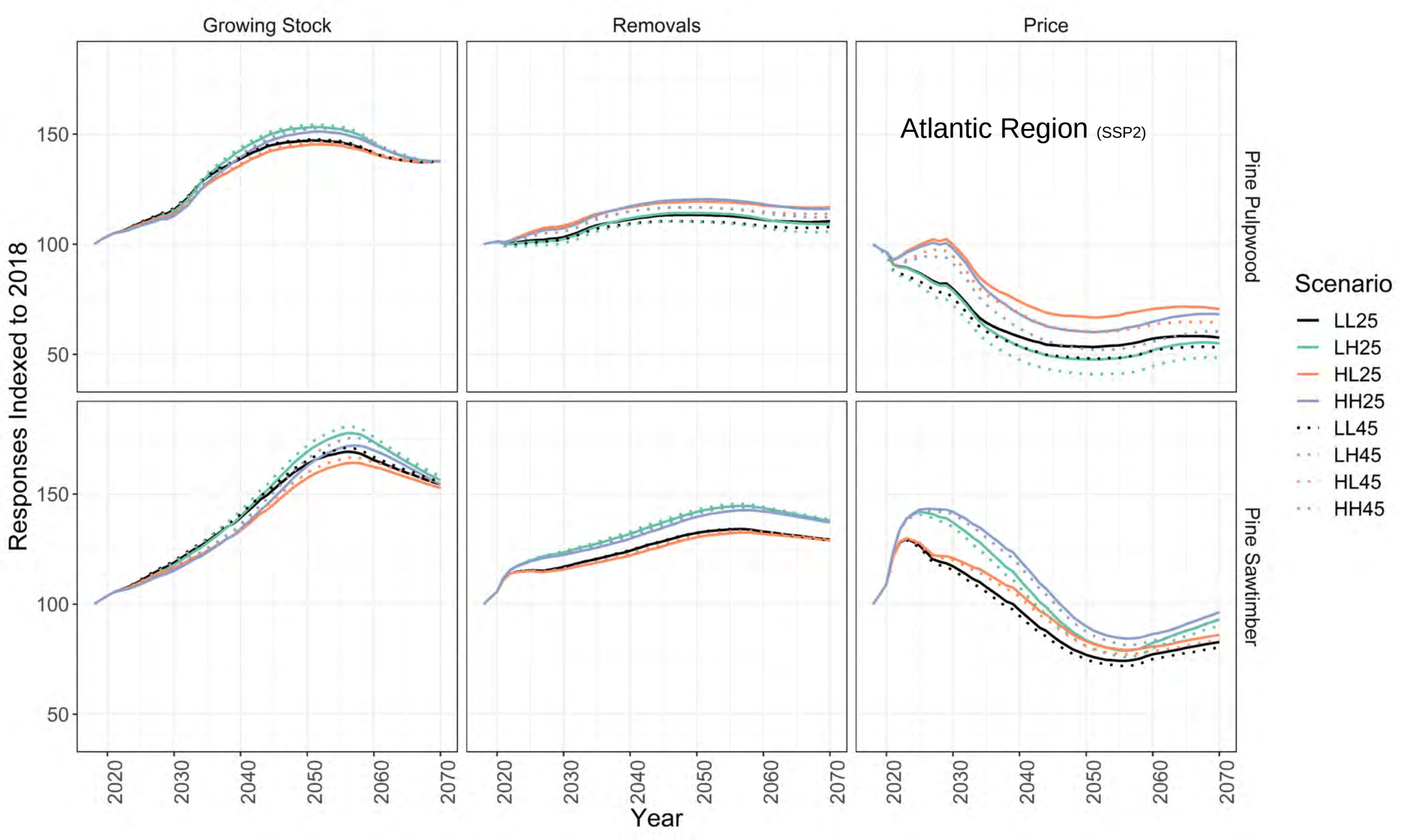
-- does not directly imply a feedstock amount,

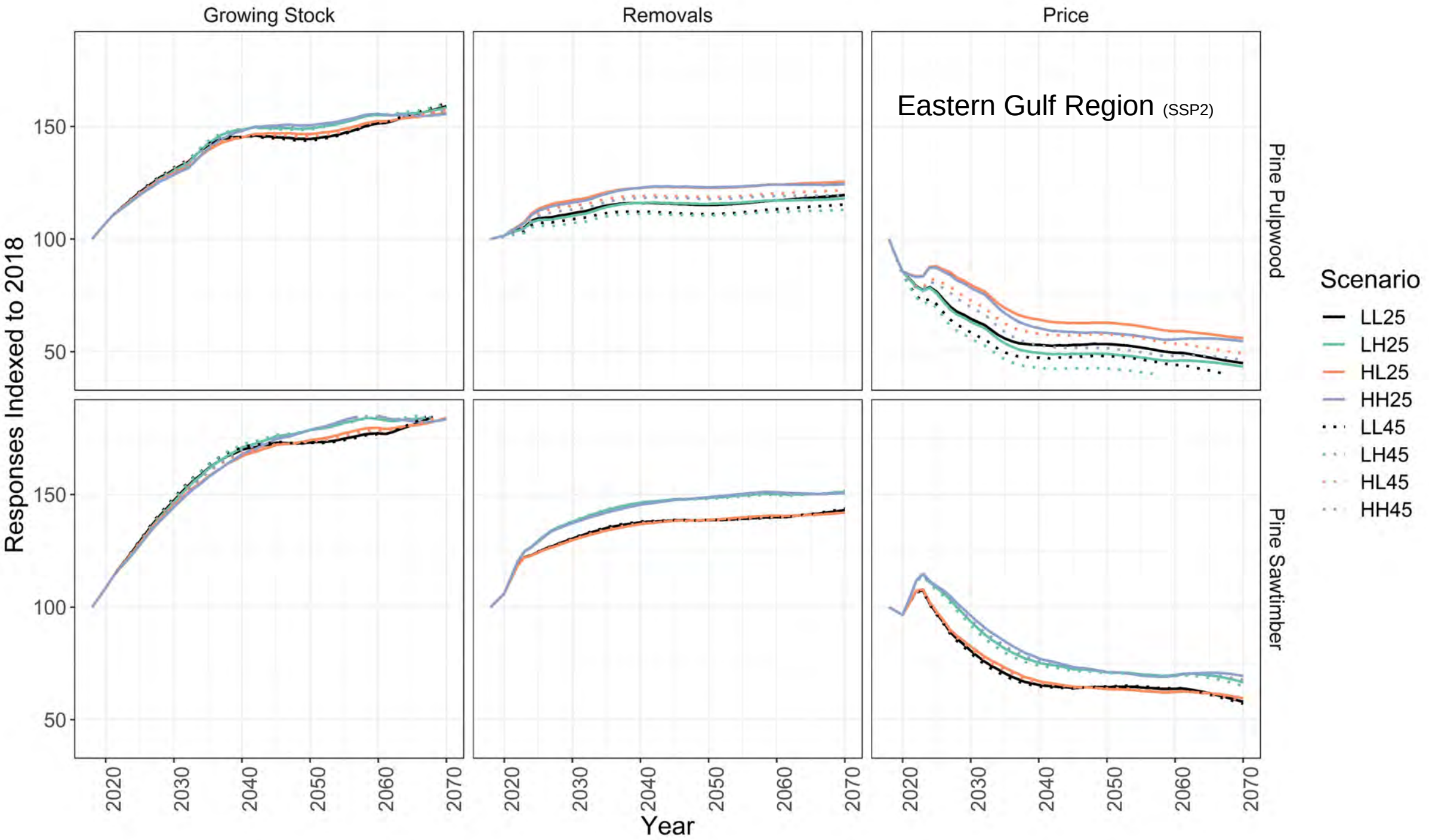
i.e, how much residue is produced alongside lumber

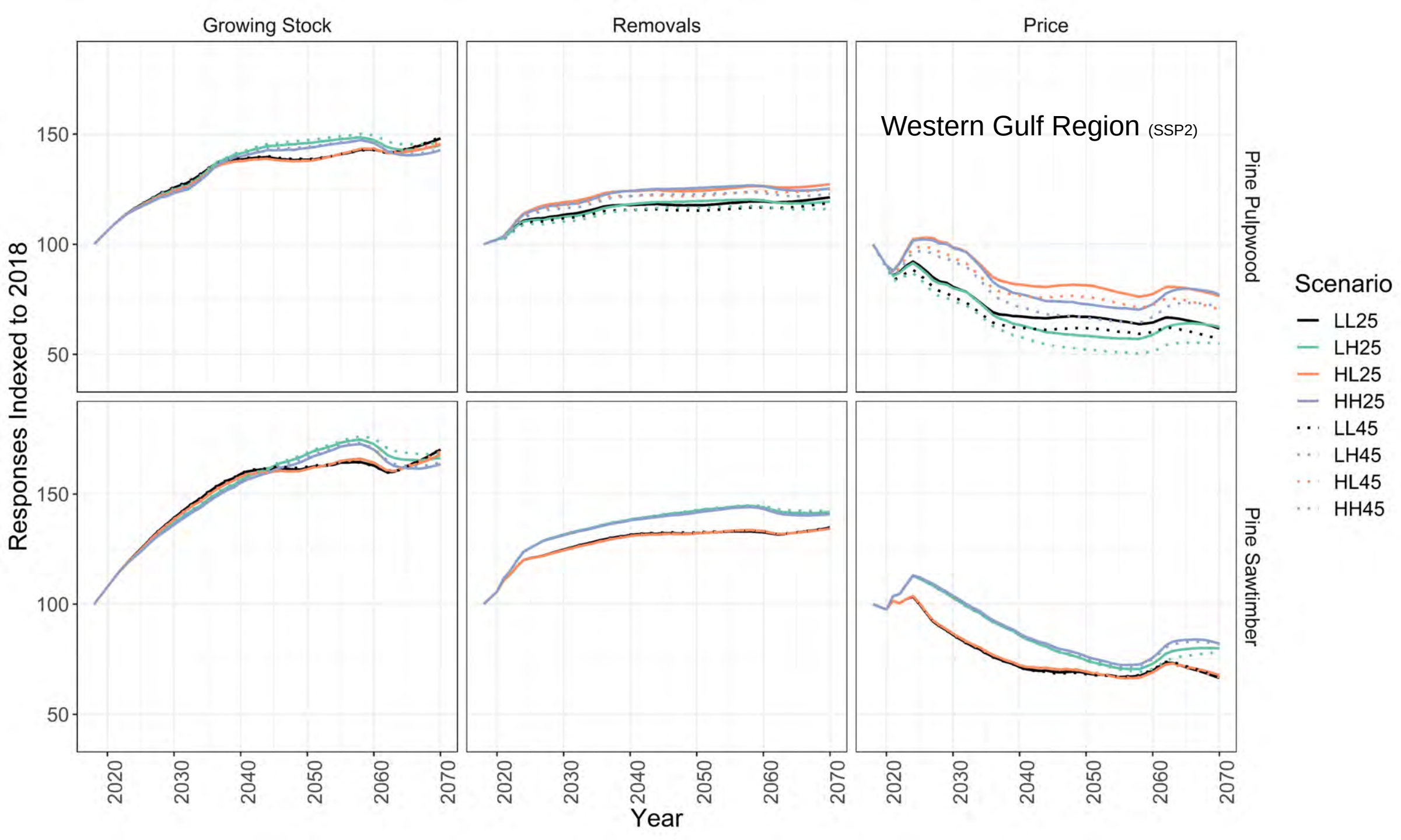
MARKET RESULTS

What to look for:

- Blue and Green are high sawtimber scenarios
- Dotted lines are cases with more sawmill residue
  (implying new sawmills produce more waste)


Growing Stock
Removals
Price
Atlantic Region (SSP2)
Pine Pulpwood
Pine Sawtimber
Responses Indexed to 2018
150
100
50
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45

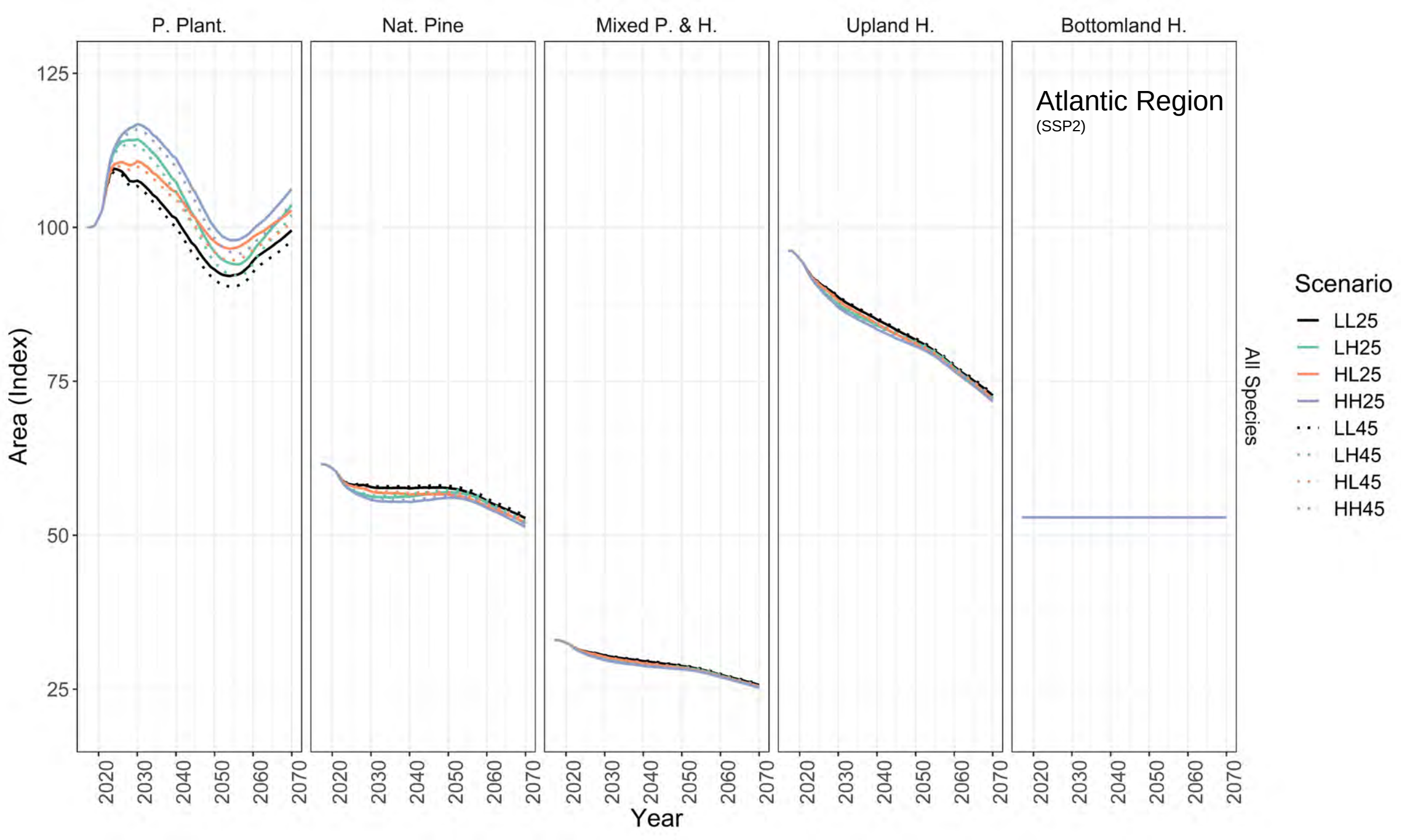

Growing Stock
Removals
Price
Eastern Gulf Region (SSP2)
Pine Pulpwood
Pine Sawtimber
Responses Indexed to 2018
150
100
50
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45


Growing Stock
Removals
Price
Western Gulf Region (SSP2)
Pine Pulpwood
Pine Sawtimber
Responses Indexed to 2018
150
100
50
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45

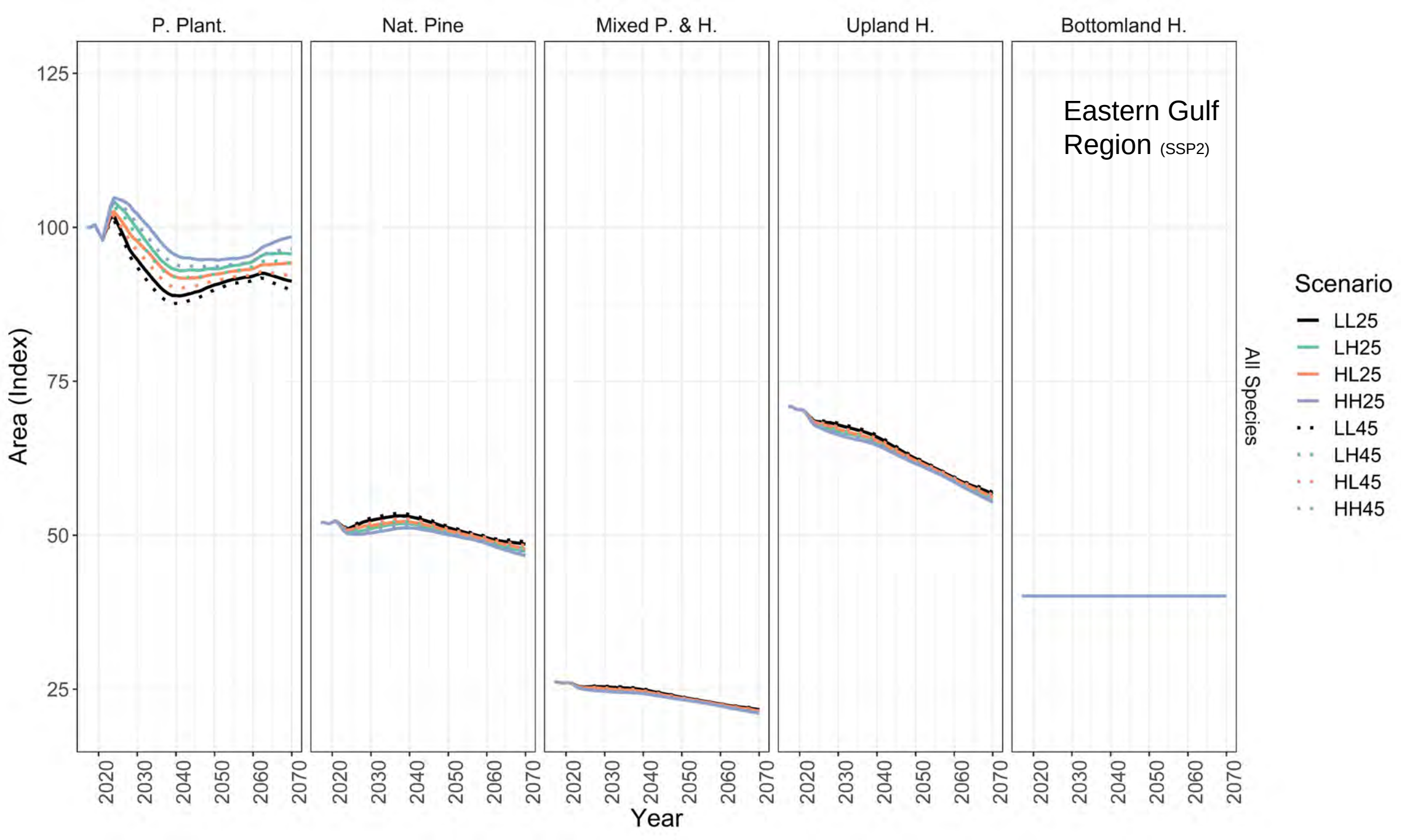
FOREST AREA

What to look for:

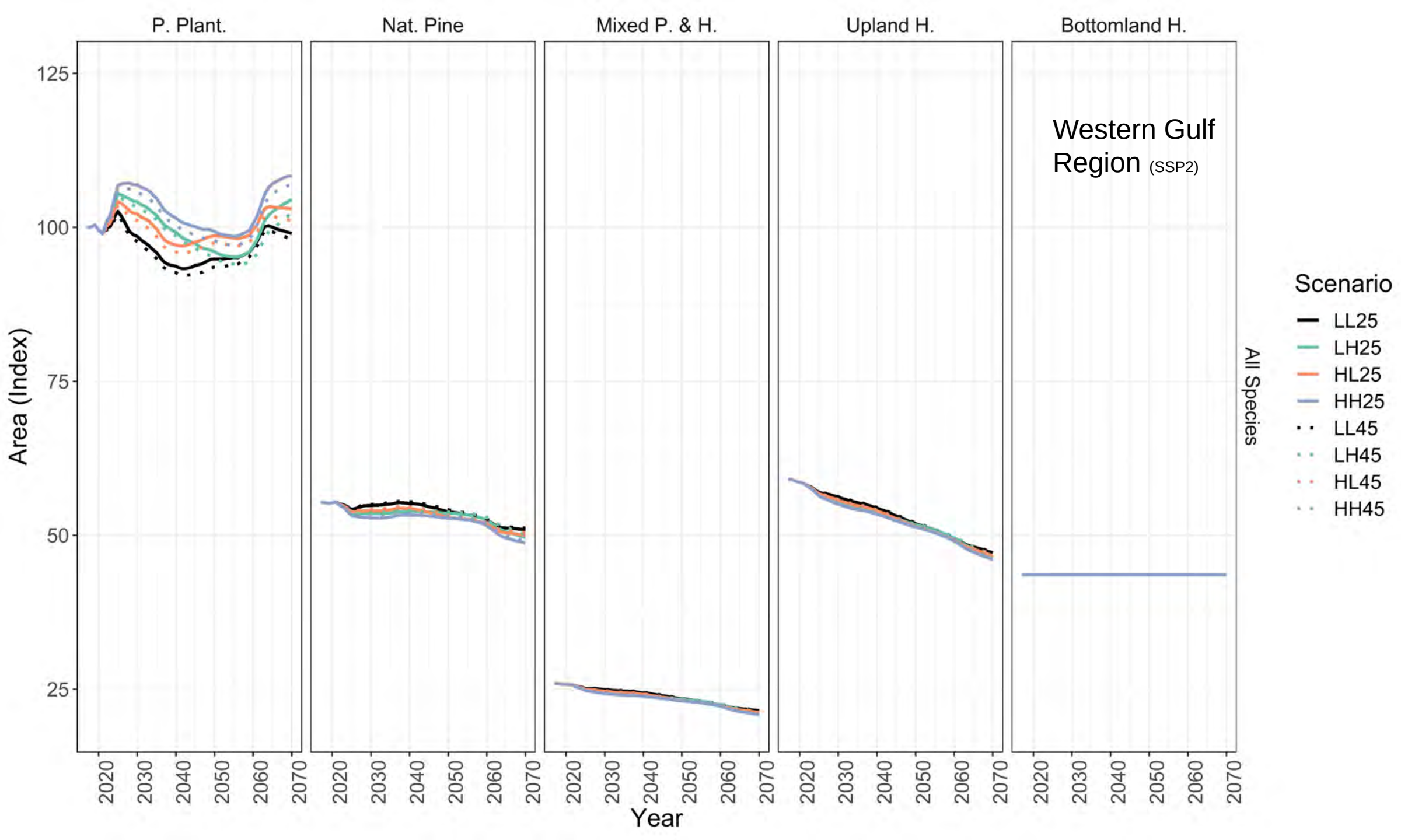
- Shows how different forest types *react* to higher pine rents
- The figure shows only one SSP scenario



FOREST AREA BY MANAGEMENT TYPE



FOREST AREA BY MANAGEMENT TYPE

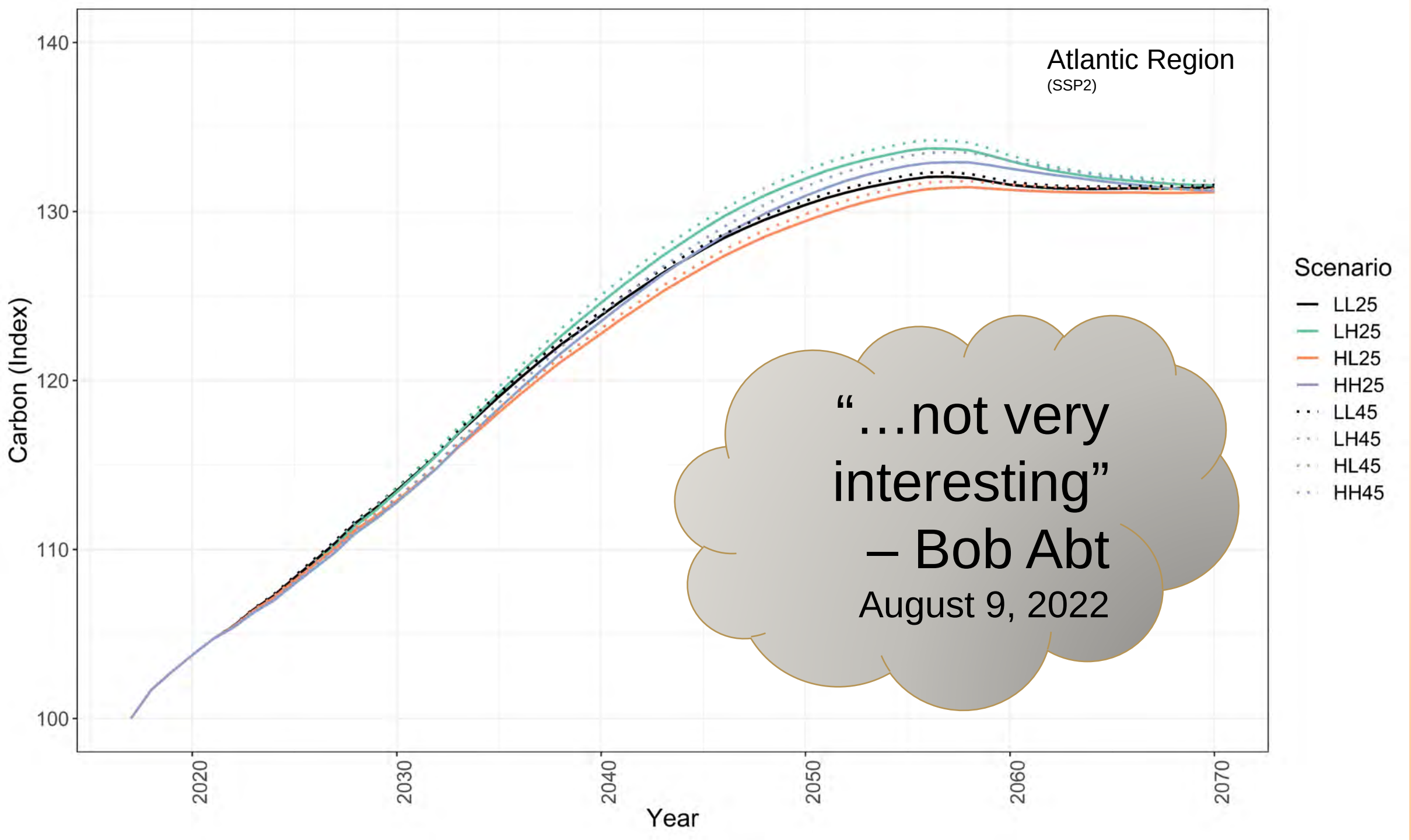


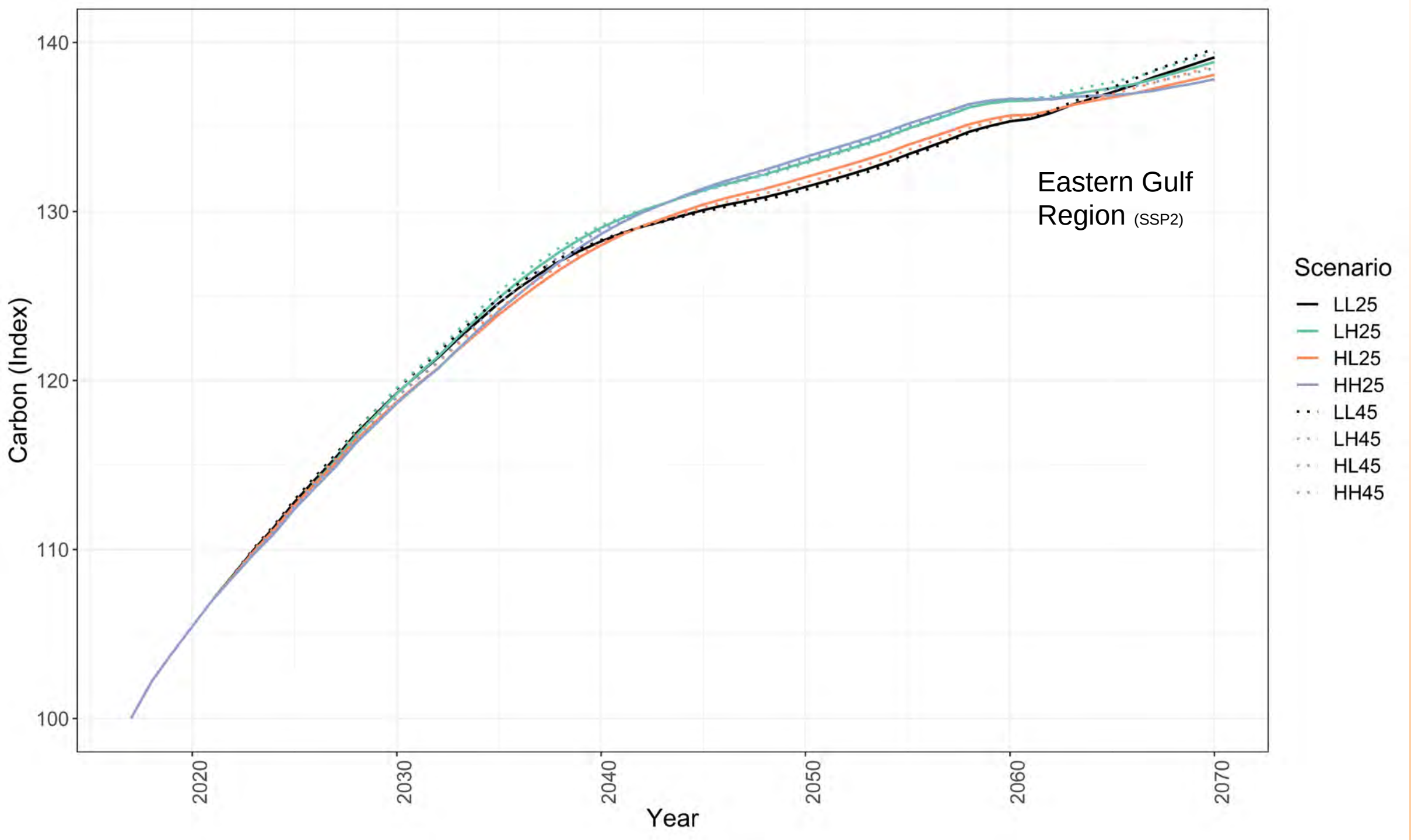
FOREST AREA BY MANAGEMENT TYPE

CARBON

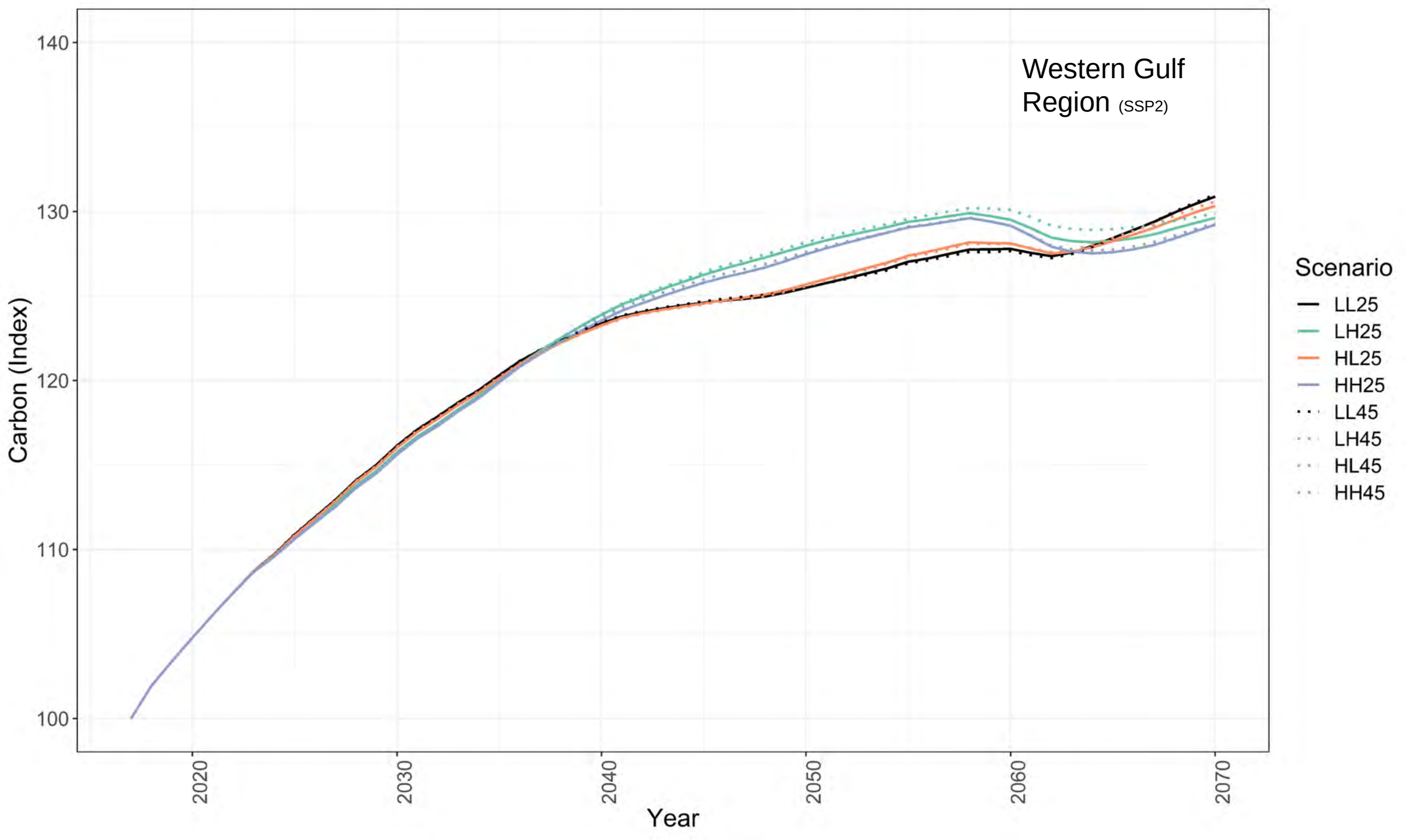
Main ideas

- In the medium term, we see a difference in forest carbon among scenarios
  - Higher sawtimber demand → higher forest carbon
  - Higher sawmill residue (offsetting pulp demand) → higher forest carbon
- In the long run, forest and land markets adapt and obscure the differences
- If you believe that the timing of carbon in the atmosphere matters (as voluntary carbon programs argue), these results matter.


Atlantic Region
(SSP2)
Carbon (Index)
140
130
120
110
100
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45
"…not very interesting"
– Bob Abt
August 9, 2022



CARBON METRICS


Western Gulf Region (SSP2)
Carbon (Index)
140
130
120
110
100
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45

Observations

Pine sawtimber residual feedback dynamics:

- Higher residual percentage reduces pulpwood harvest, feeding back into higher pulpwood growing stock.
- Higher pulpwood growing stock later grows into sawtimber growing stock, leading to an inventory-based sawtimber price decrease.
- Lower pine sawtimber price reduces pine plantation accumulation.

Observations

Forest carbon accumulation:

- In the medium term (2030-2050), the highest forest carbon is achieved by HL45*
  - (high sawtimber demand, low pulpwood demand, high sawmill residual rate)
- By 2070, the LL45 passes or equals the other cases in forest carbon.
  - Note: static demand curve from 2030-2070. Under increasing demand, higher prices would support higher pine plantation area, and the carbon gap in HL45 could be maintained.

* In East Gulf, HH is *tied*

Further Study and Limitations

Alternative Land Use Models:

- In progress – a model that adds agricultural rents (using it in a projection would require an exogenous ag rent scenario)

Variation by SSP:

➢Sensitivity analysis on SSP indicated small differences between SSP1 and 2. Interestingly, in SSP3 (higher pop./inc. growth): scenarios produced more forest carbon in the long run. The empirical model estimates that ag is more sensitive (negative relationship) to pop/income, and lower ag share leaves room for more forest.

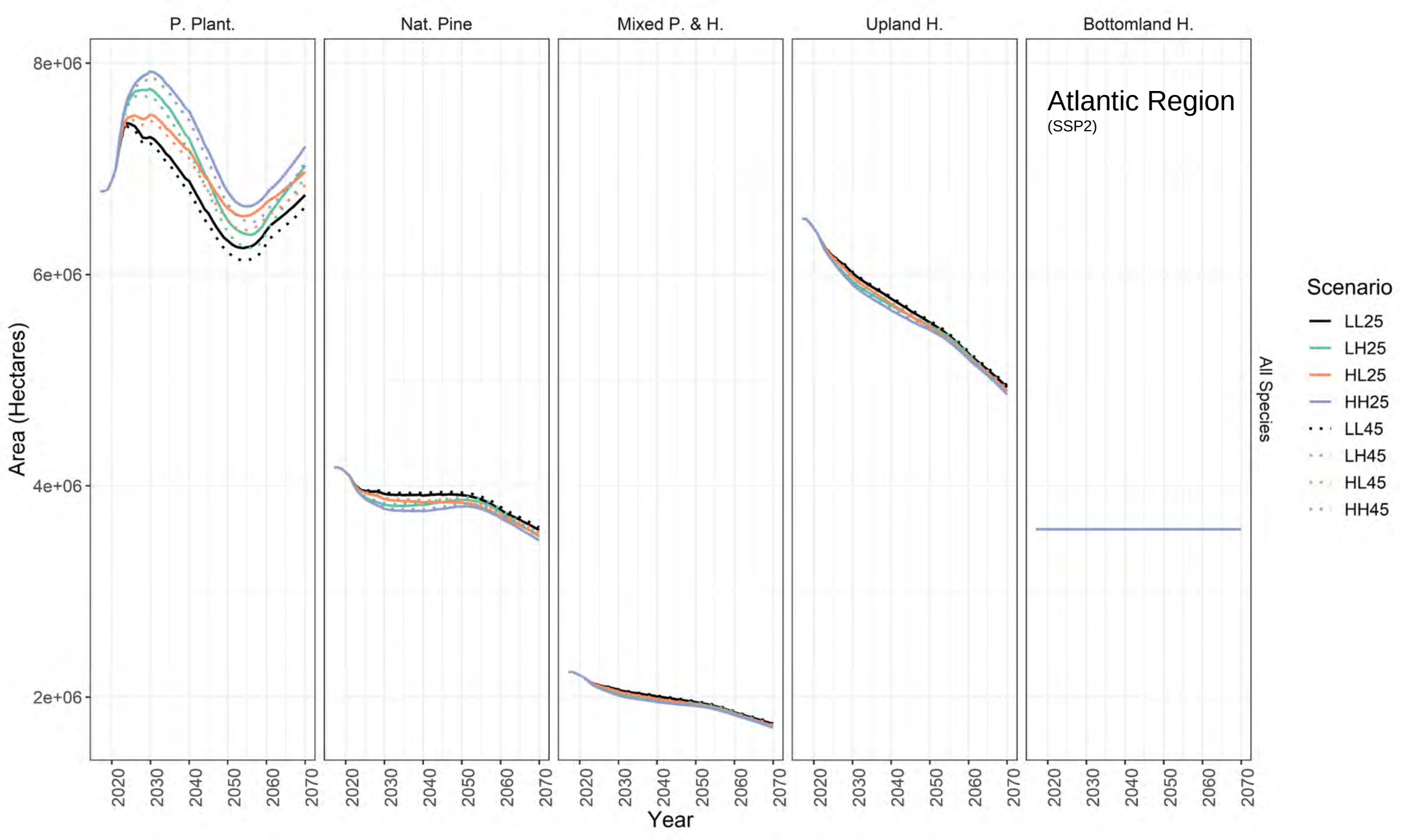
New runs will be needed using new FIA volume equations!

THANKS

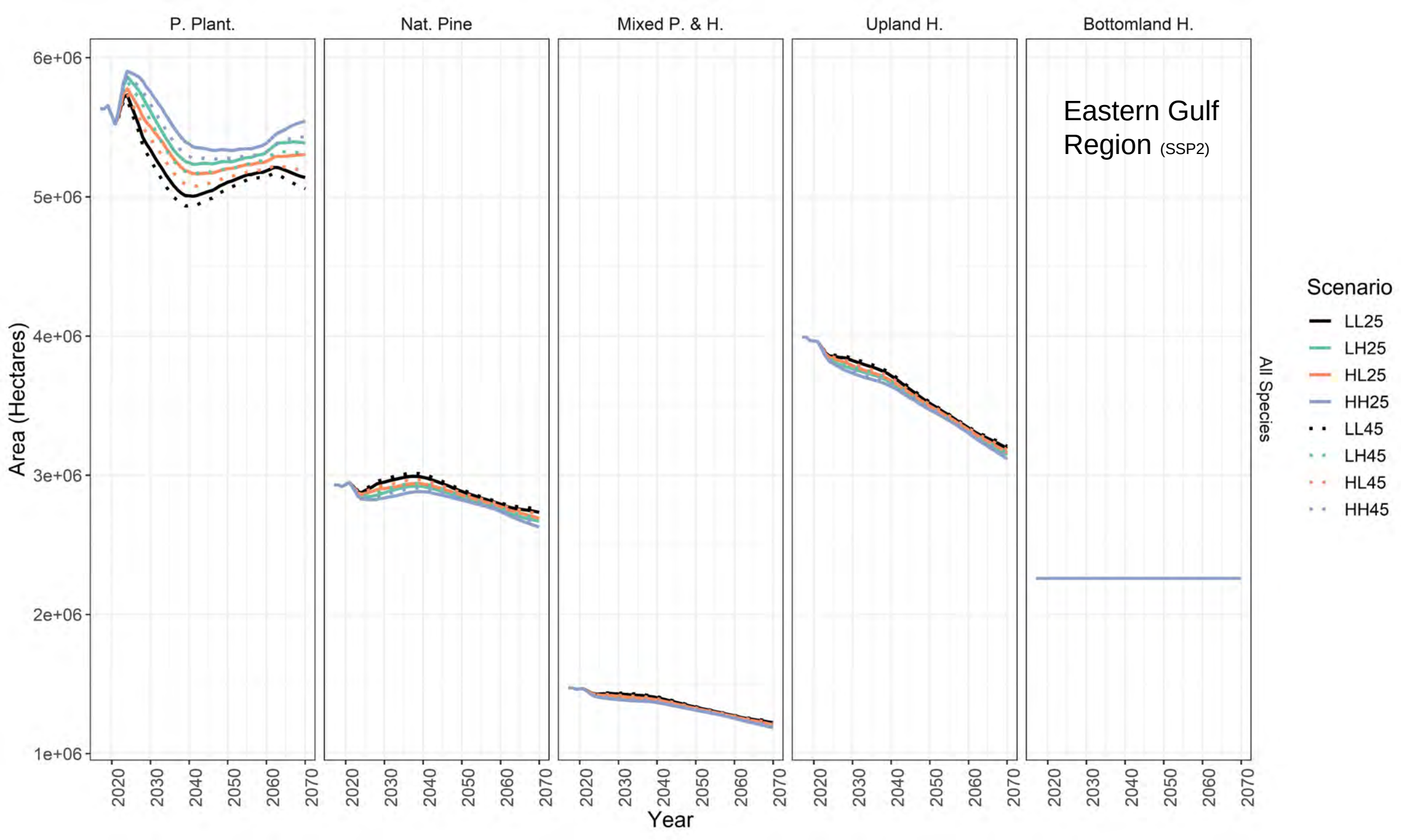
Contact: jesse.henderson2@usda.gov

SUPPLEMENTARY MATERIALS

FOREST AREA (ABSOLUTE)



FOREST AREA BY MANAGEMENT TYPE



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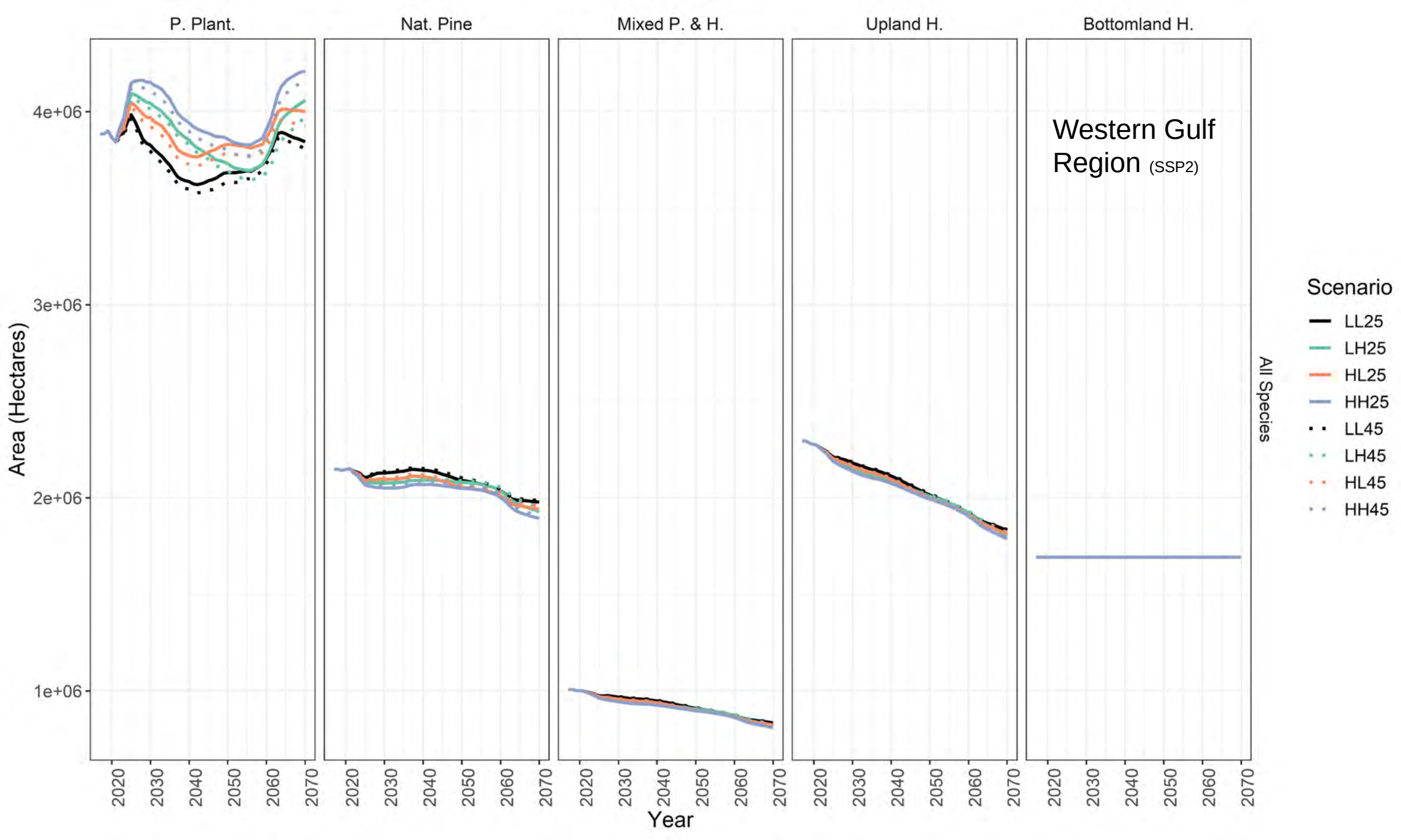
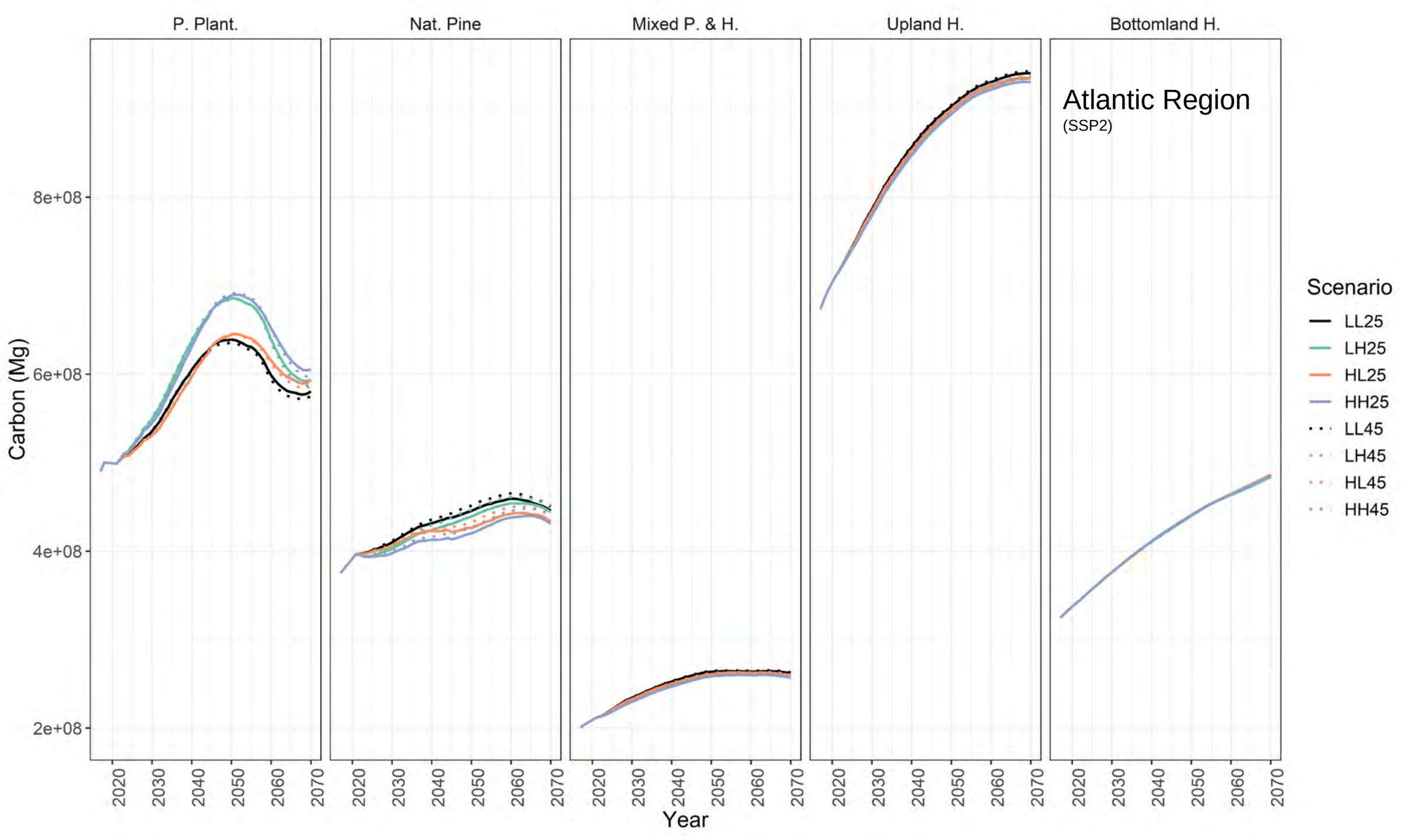
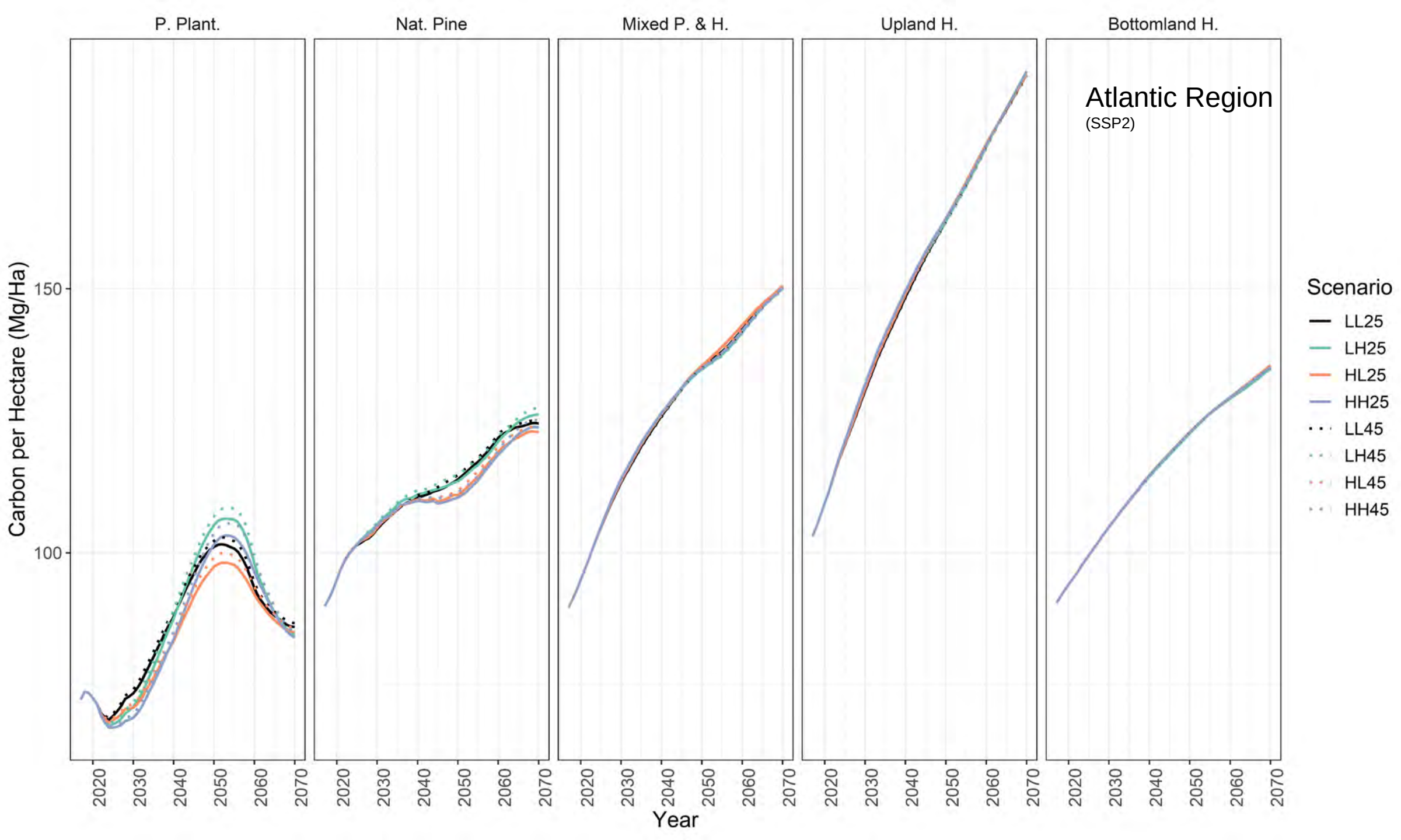


FOREST AREA BY MANAGEMENT TYPE

CARBON IN THE ATL



CARBON METRICS



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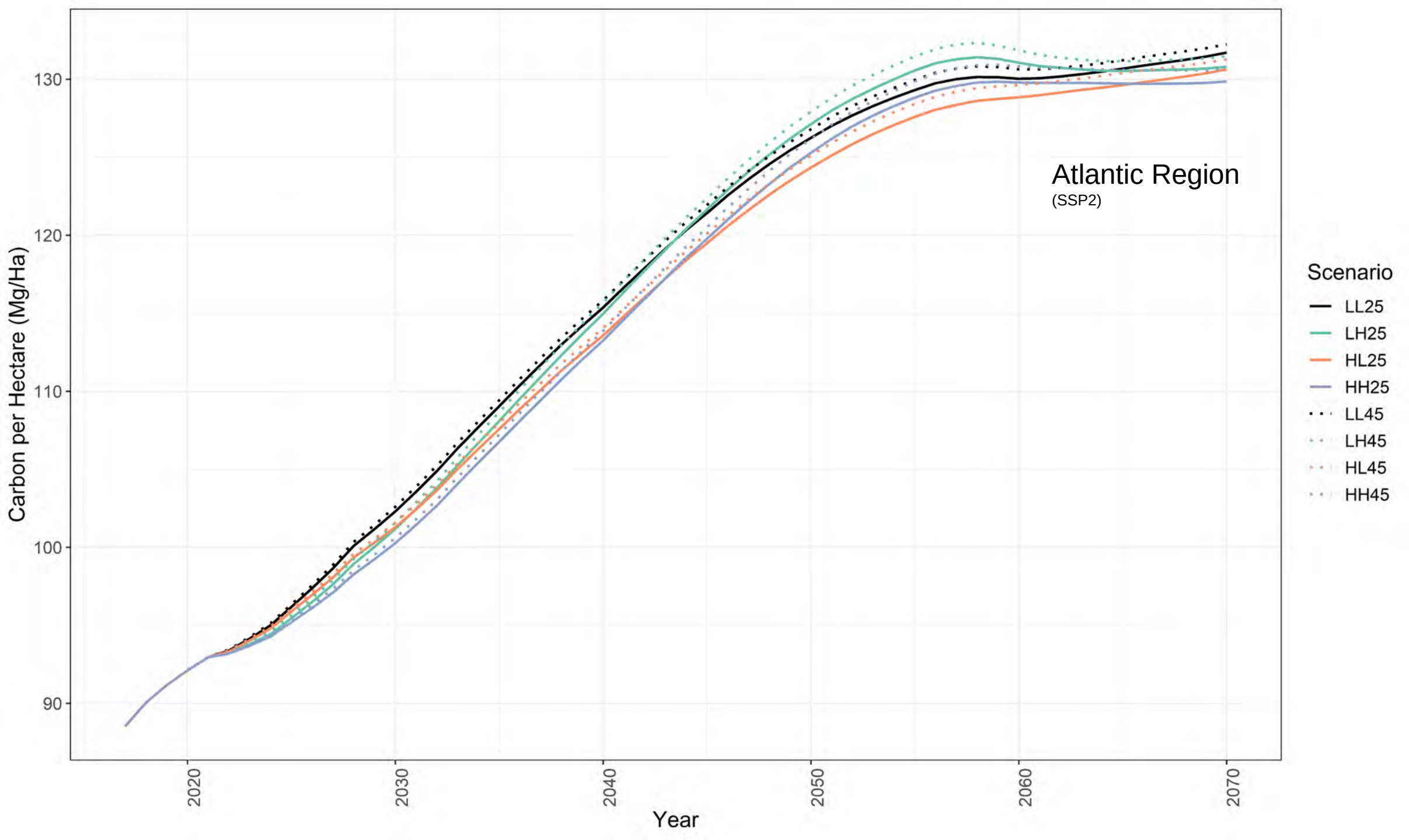
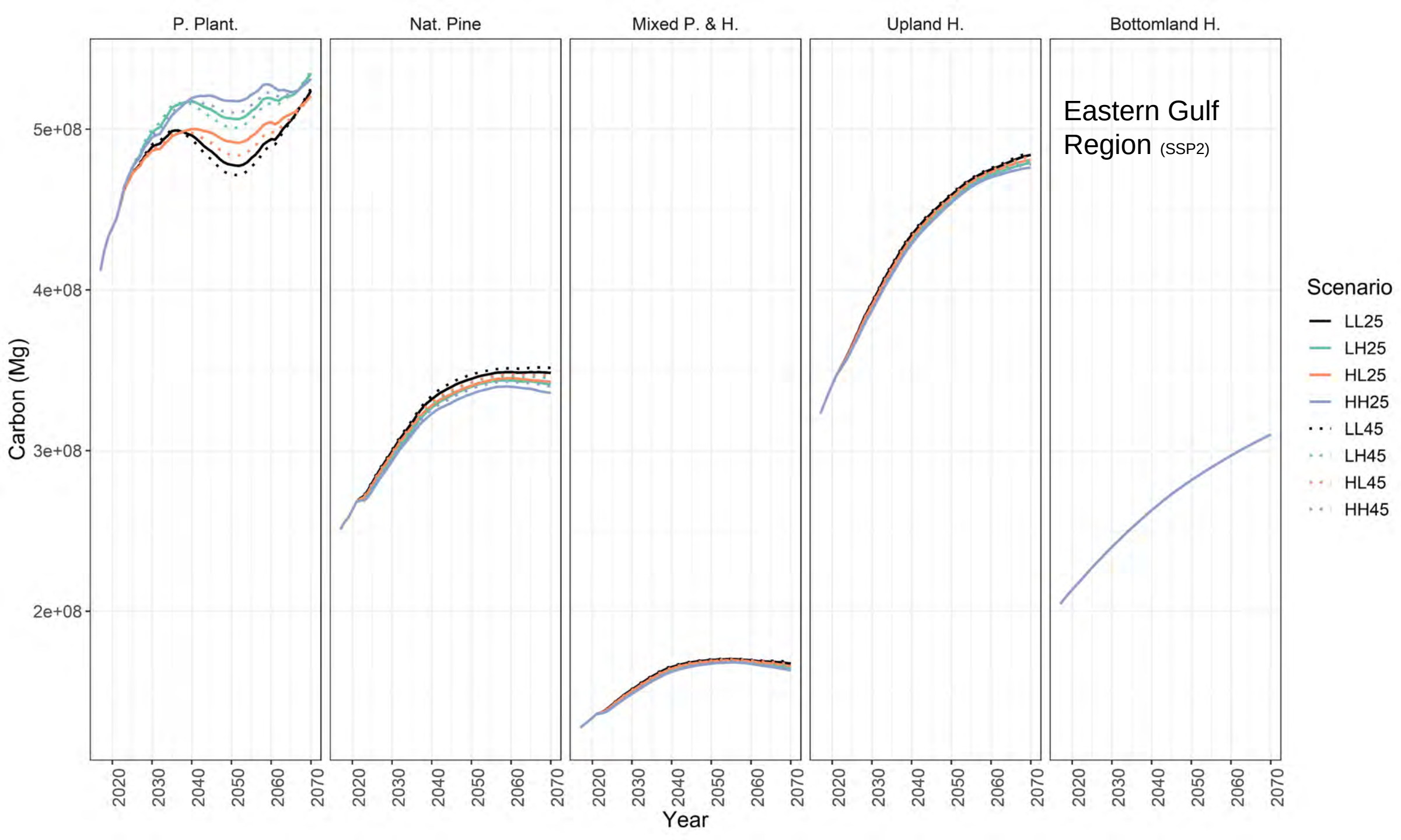
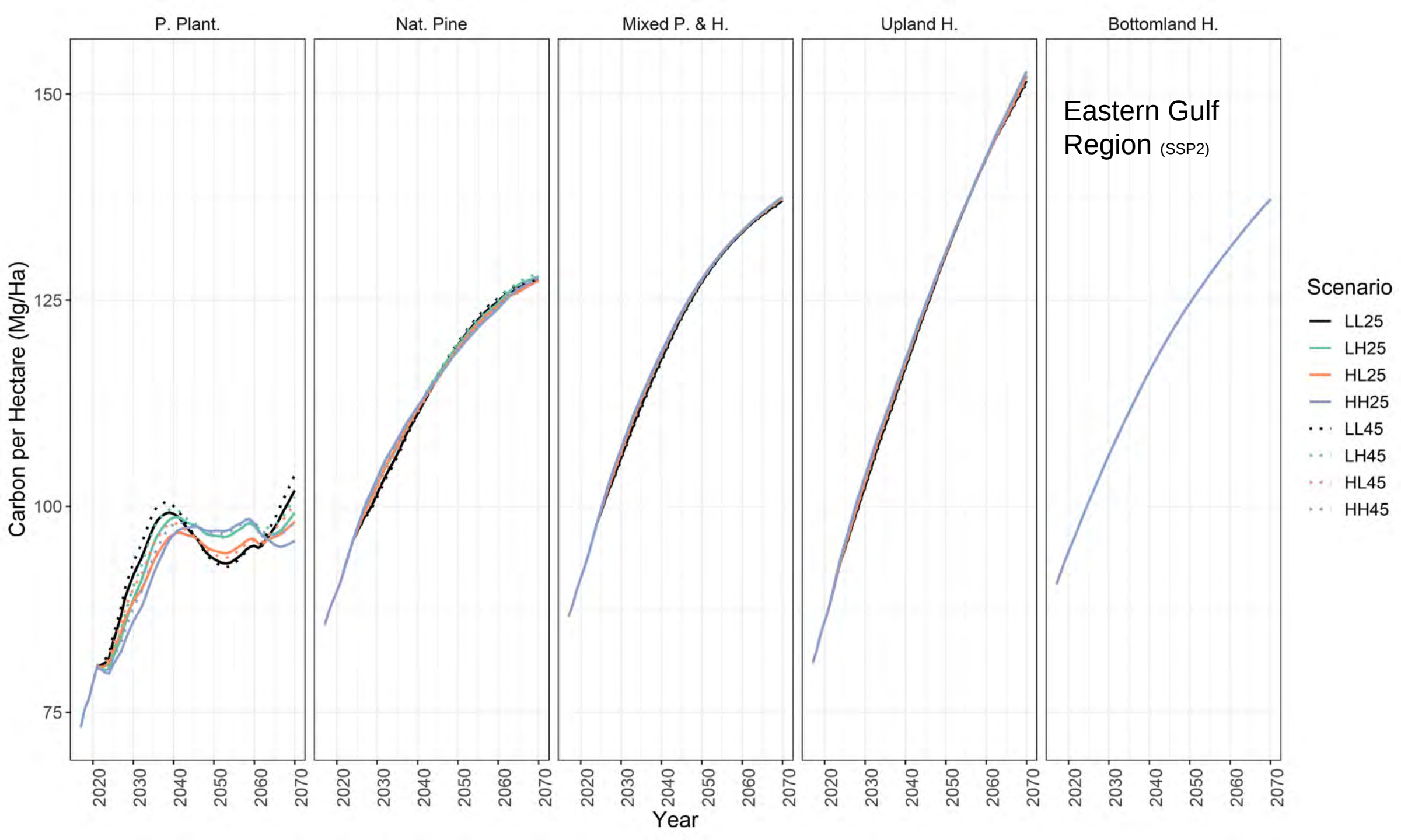


CARBON METRICS

CARBON IN EGF



CARBON METRICS



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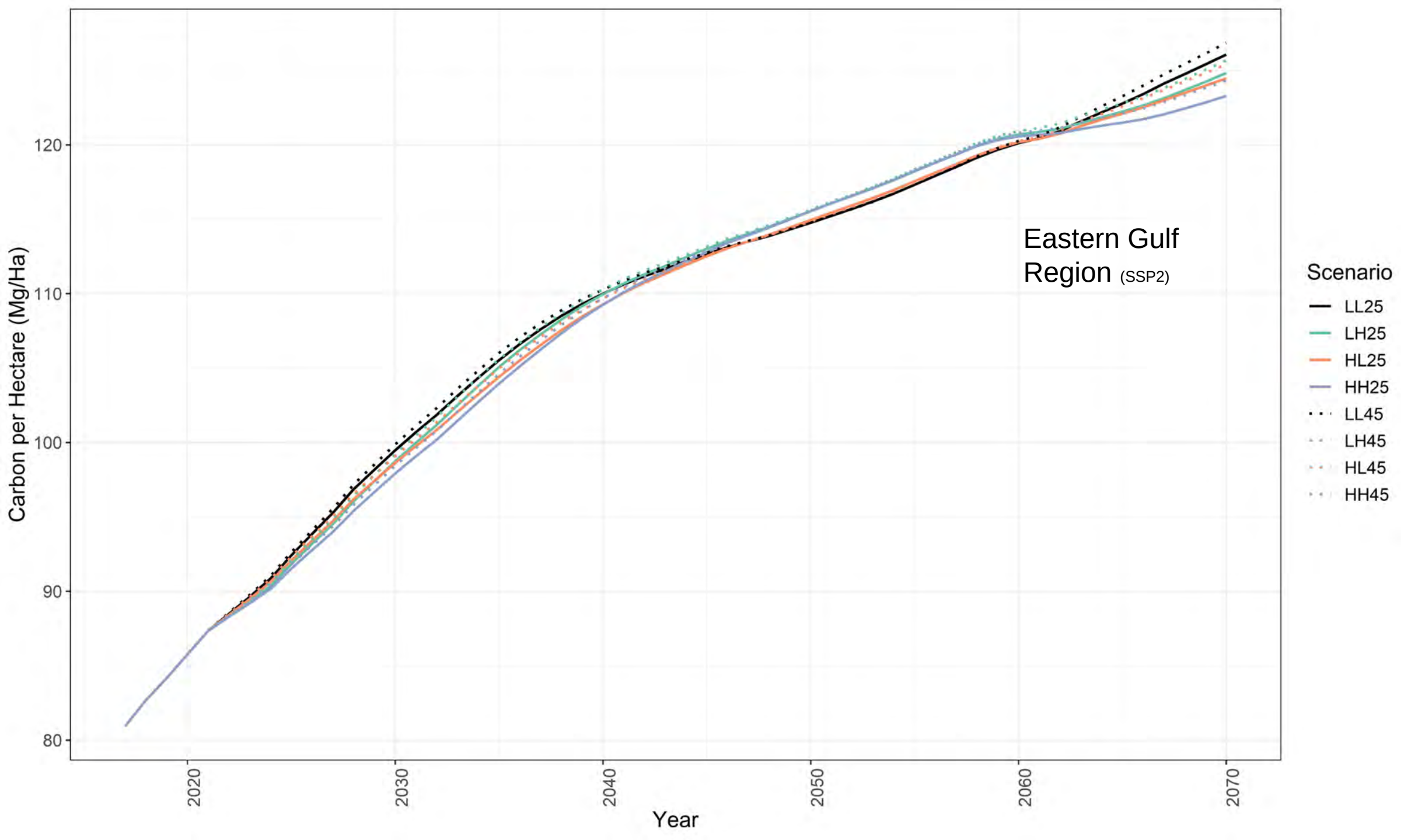
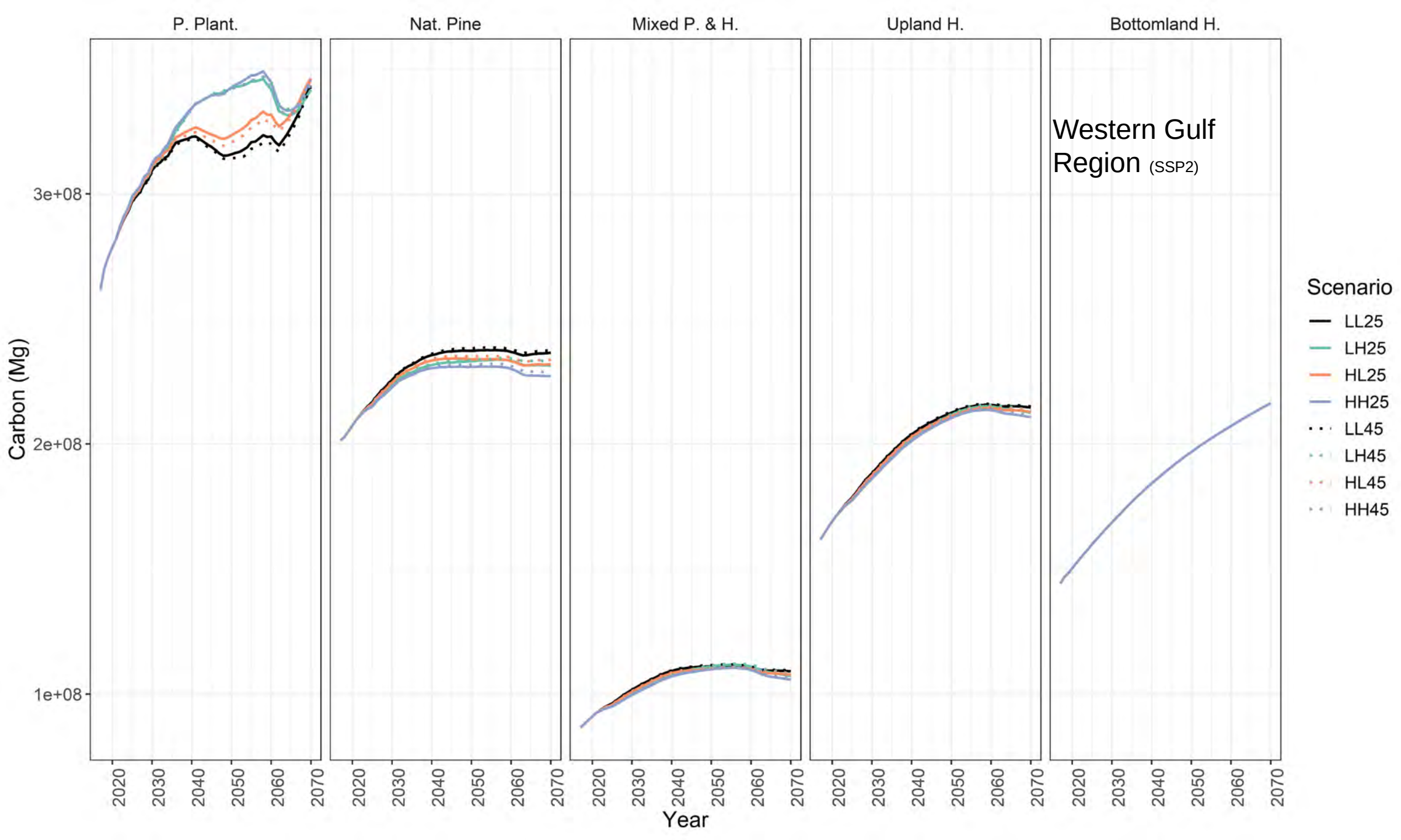
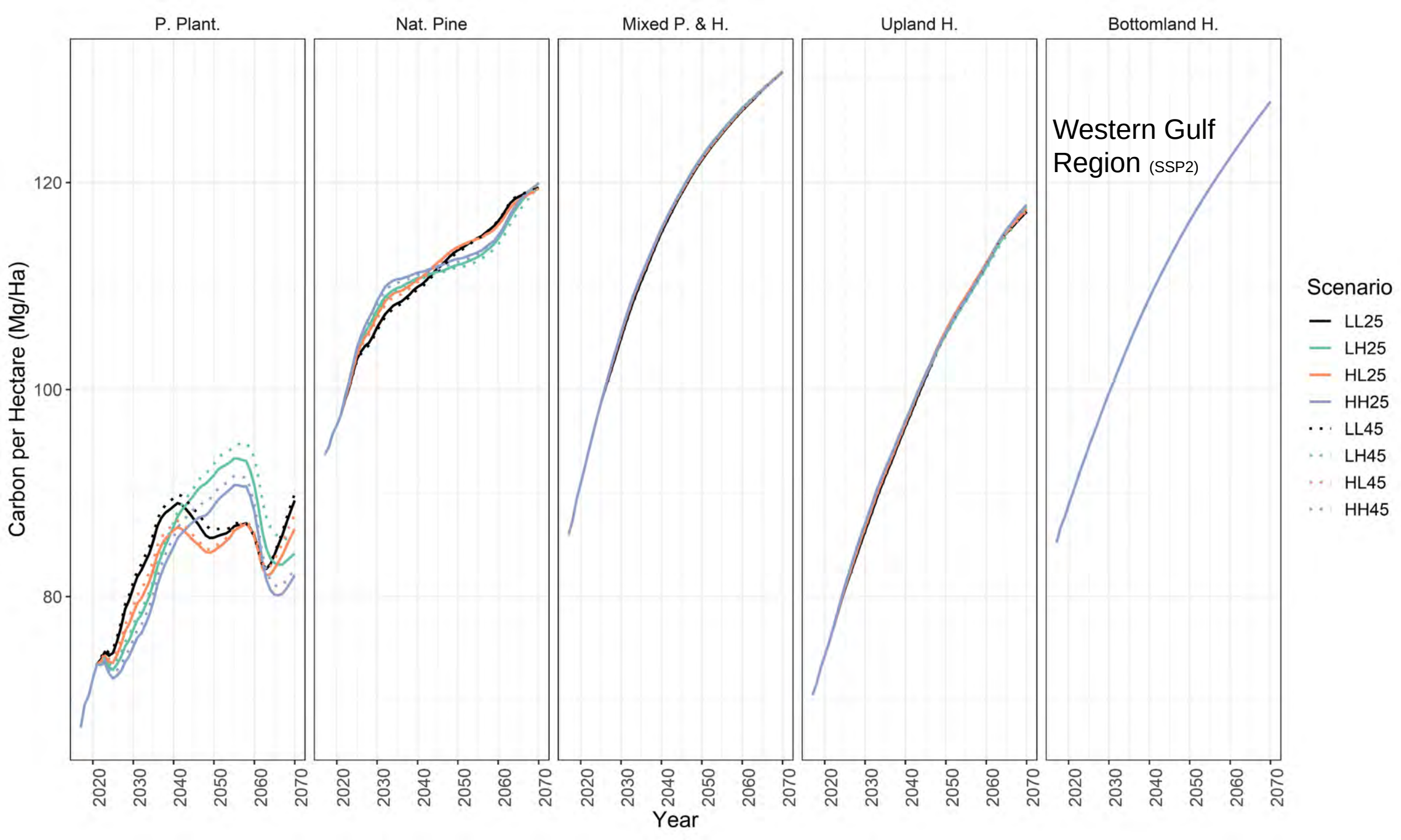


CARBON METRICS

CARBON IN WGF



CARBON METRICS



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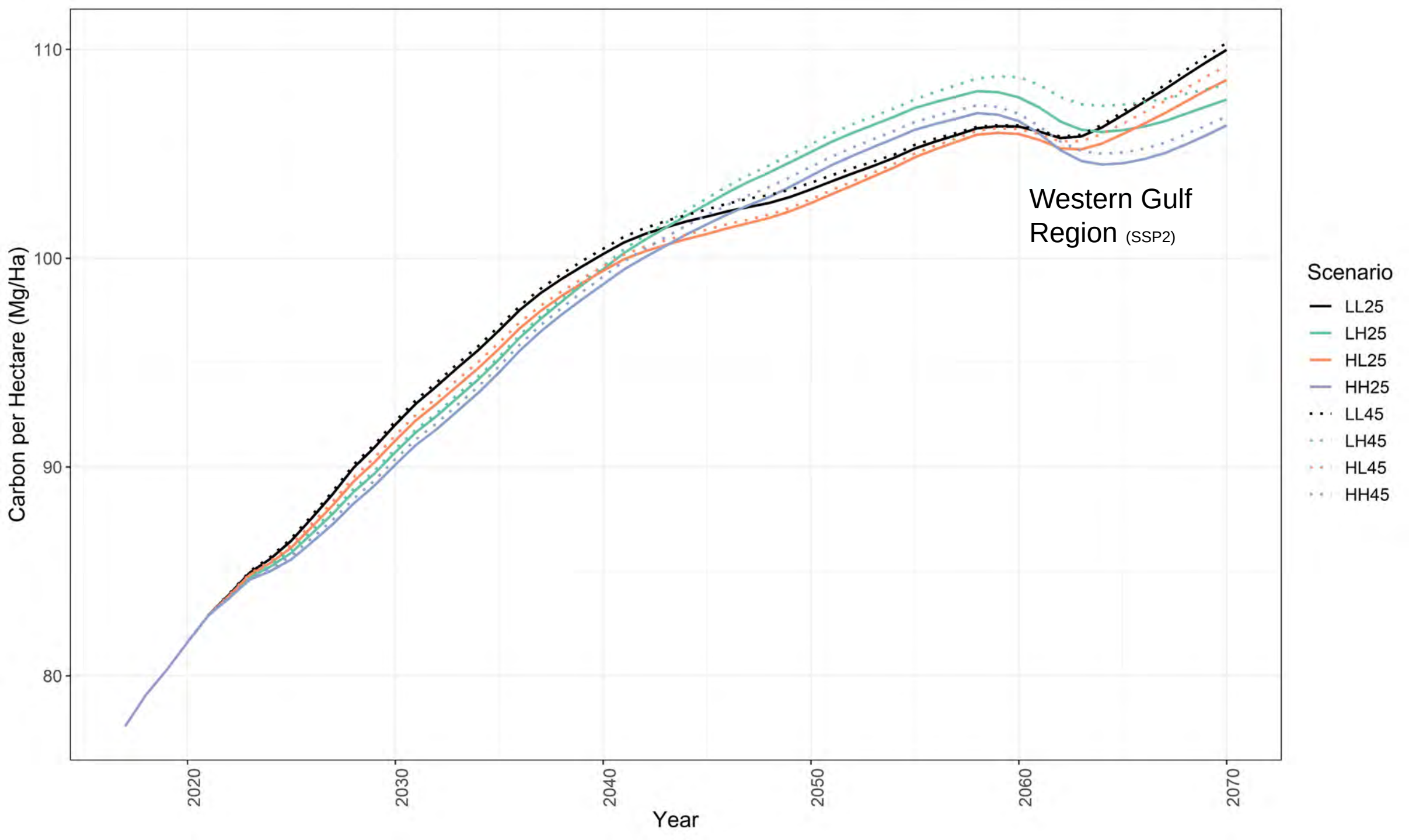
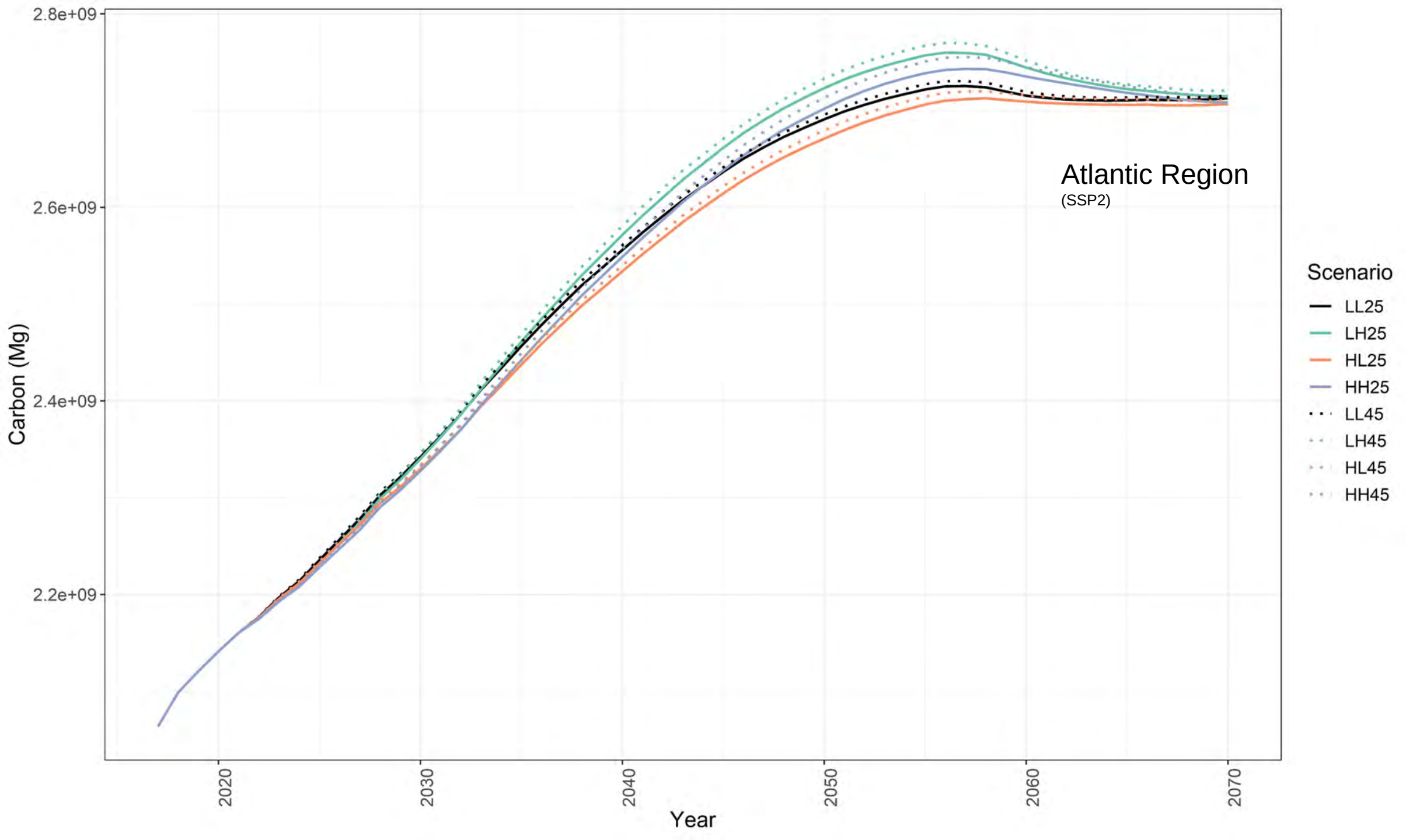

Western Gulf Region (SSP2)
Carbon per Hectare (Mg/Ha)
110
100
90
80
2020
2030
2040
2050
2060
2070
Year
Scenario
LL25
LH25
HL25
HH25
LL45
LH45
HL45
HH45

CARBON



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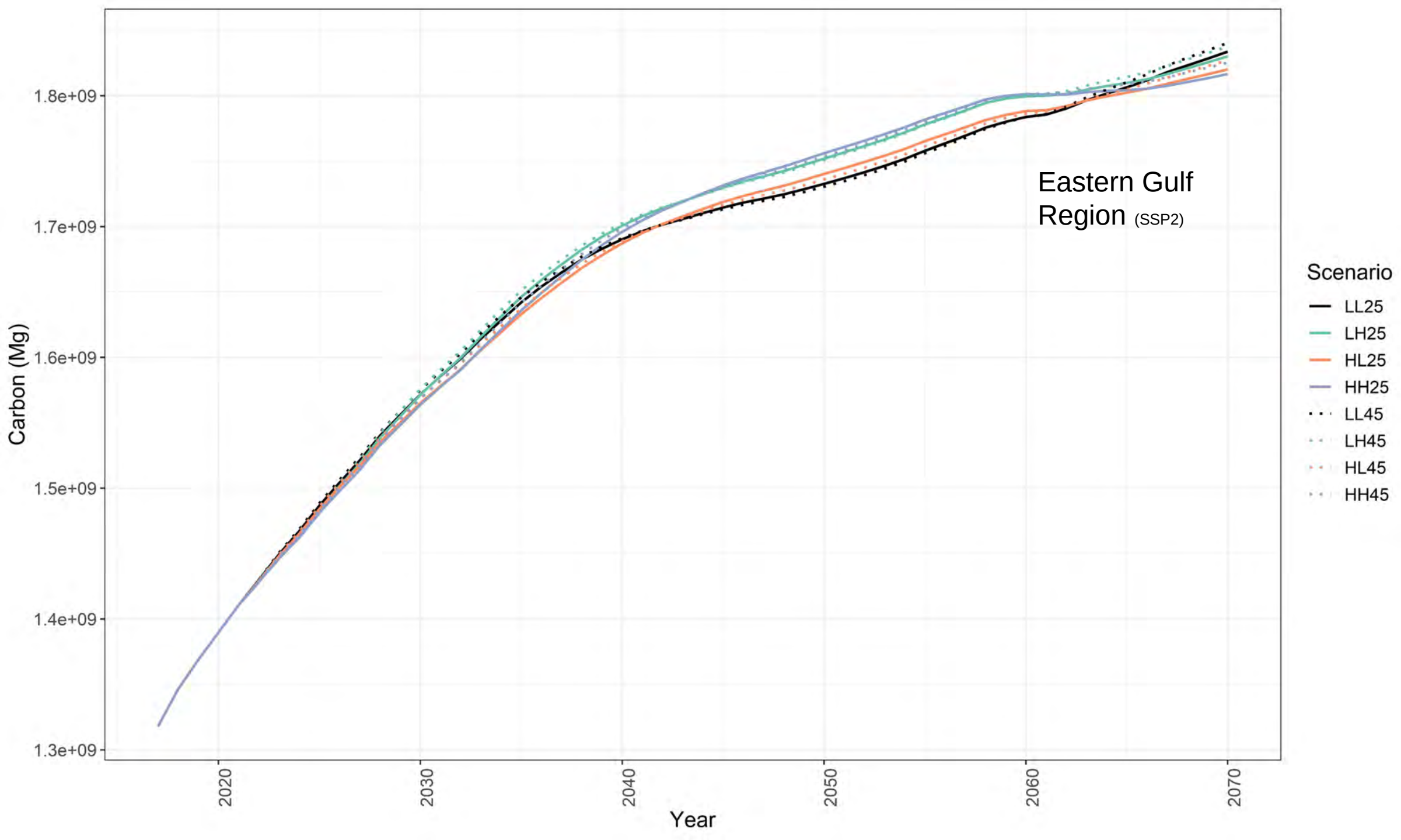

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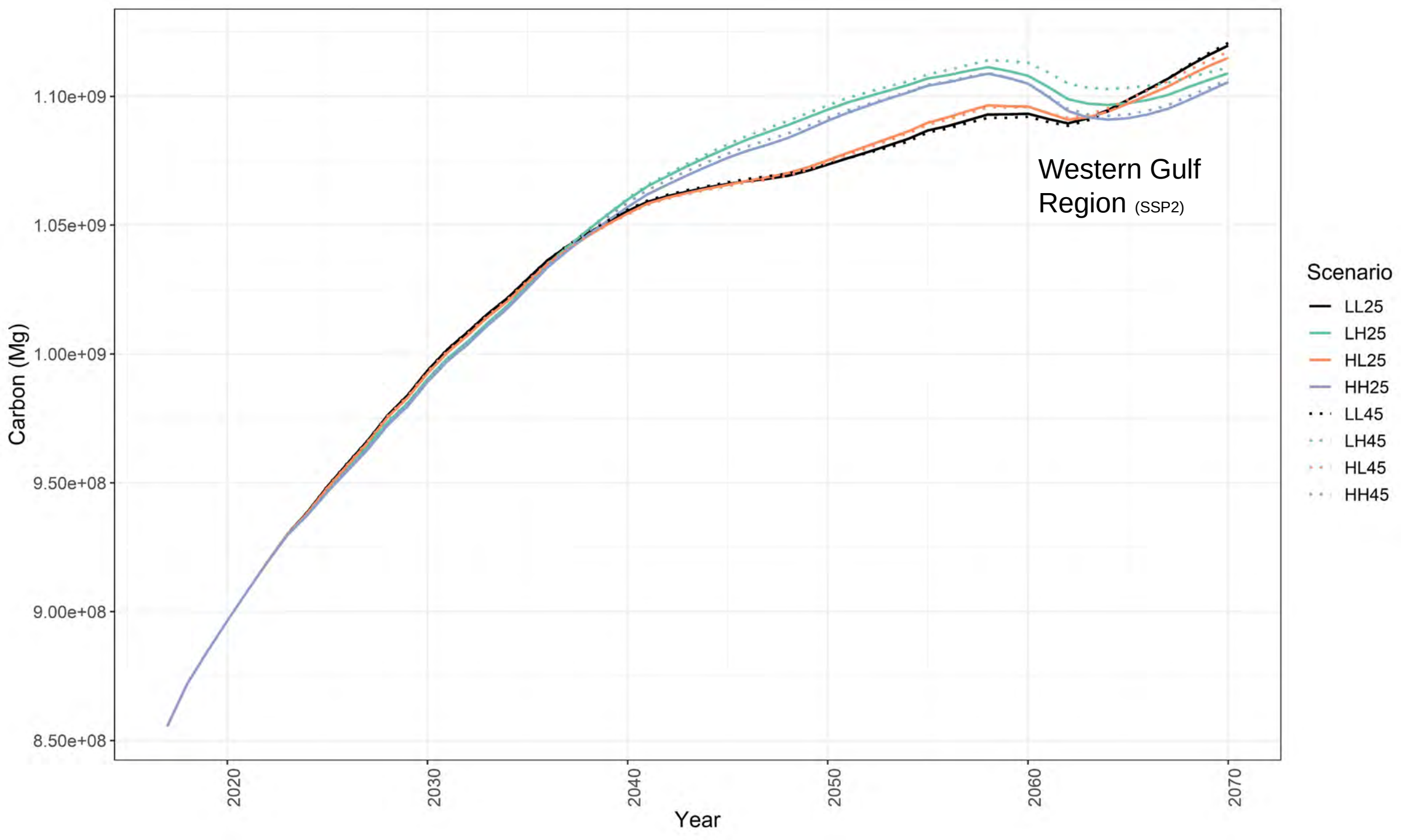

CARBON METRICS