How might climate change affect forest growth and what can we do about it?

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Acknowledgements

Collaborators (alphabetical):

- Sarah Beukema
- Dave Coates
- Anouschka Hof
- David Mladenoff
- Craig Nitschke
- Robert Scheller

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- Werner Kurz, Canadian Forest Service
- Bill Golding, Forest Manager for the Wetzin'kwa Community Forest, and
- Dave Duncan & Marie-Lou Lefrancois, BCTS Babine

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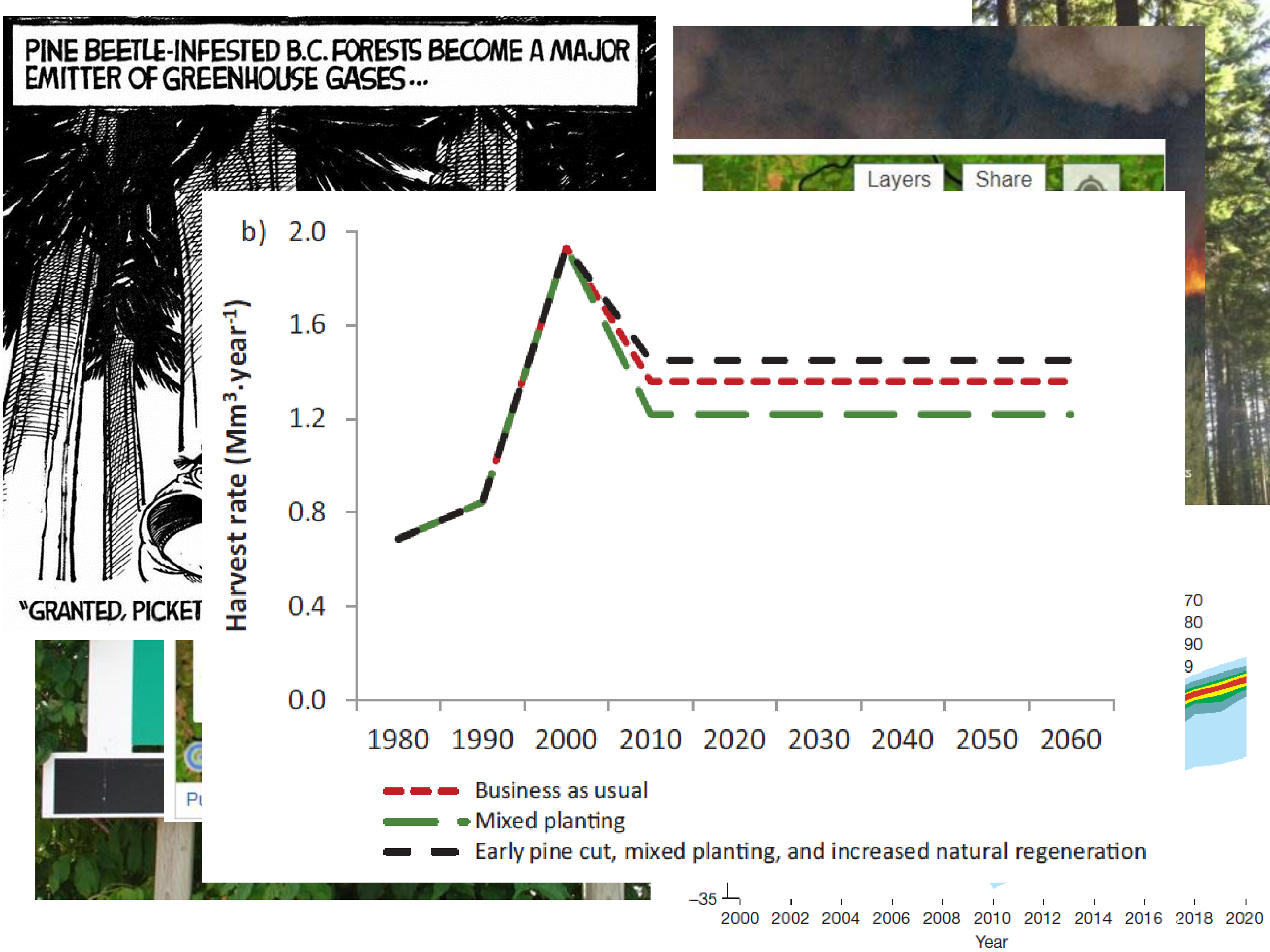

PINE BEETLE-INFESTED B.C. FORESTS BECOME A MAJOR EMITTER OF GREENHOUSE GASES...
"GRANTED, PICKET
Layers
Share
b)
2.0
1.6
1.2
0.8
0.4
0.0
Harvest rate (Mm³.year⁻¹)
1980 1990 2000 2010 2020 2030 2040 2050 2060
Business as usual
Mixed planting
Early pine cut, mixed planting, and increased natural regeneration
70
80
90
9
−35
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020
Year

Scope

Identifying climate change impacts on a managed landscape.

Assess how can this information help us manage our forests in the future?

- Timber supply
- Carbon
- Species composition

All models are wrong, some models are useful.
~G.E. Box

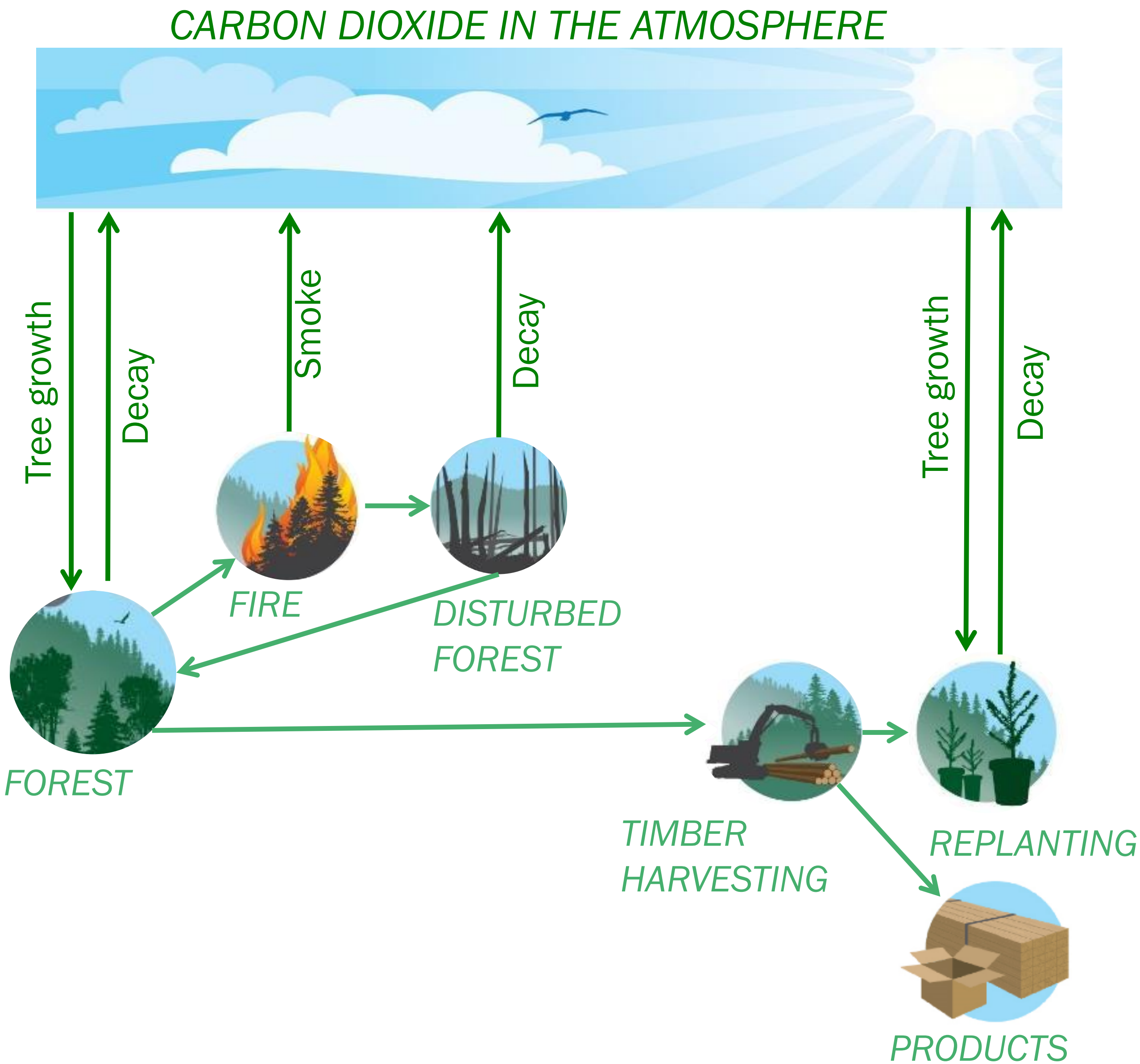
…. And I'm not a wizard…
~ C.C.Dymond

Why do we care about forest carbon?

Climate change is forcing us

- Concerns about CO_2 build up in the atmosphere.
- Questions about the role of BC forests and forest sector in affecting atmospheric GHG concentrations.
- Changing social license to operate.
- New questions for resource managers.
- New opportunities for business.

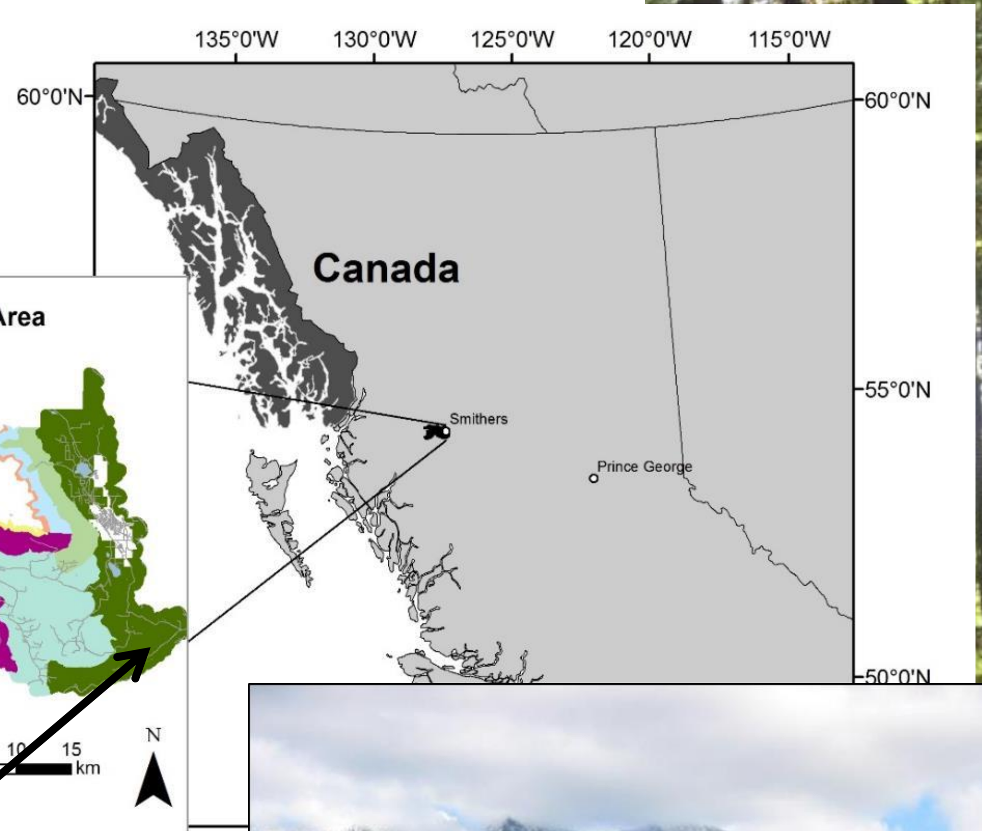
Forest carbon cycle

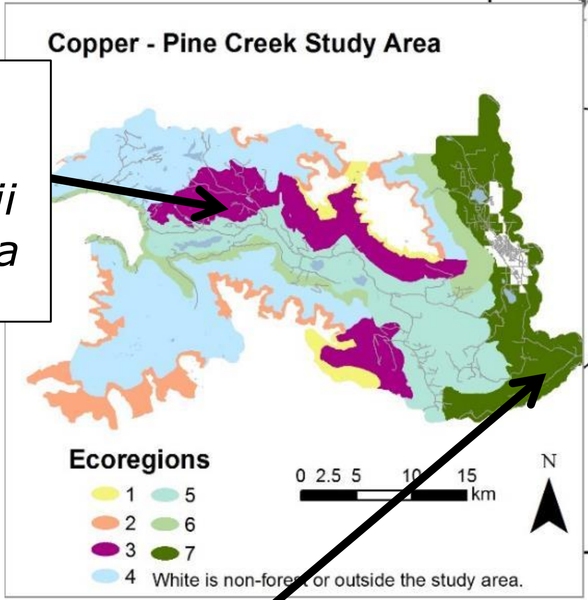


Part 1: Contrasting climate change effects in the temperate forests of northwestern British Columbia

Copper-Pine Creek study area

73,400 ha
7 LANDIS-II ecoregions



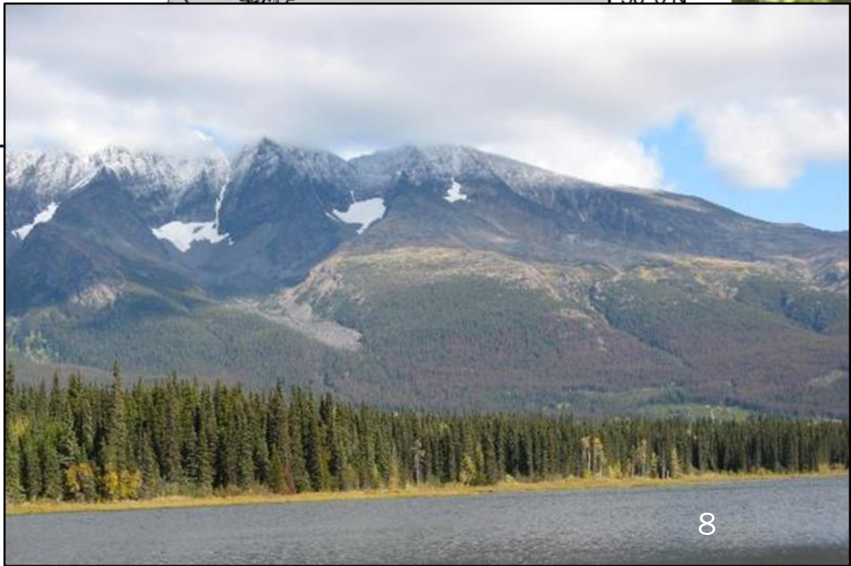


Region 3: cold

Picea Englemannii & *Abies lasiocarpa*

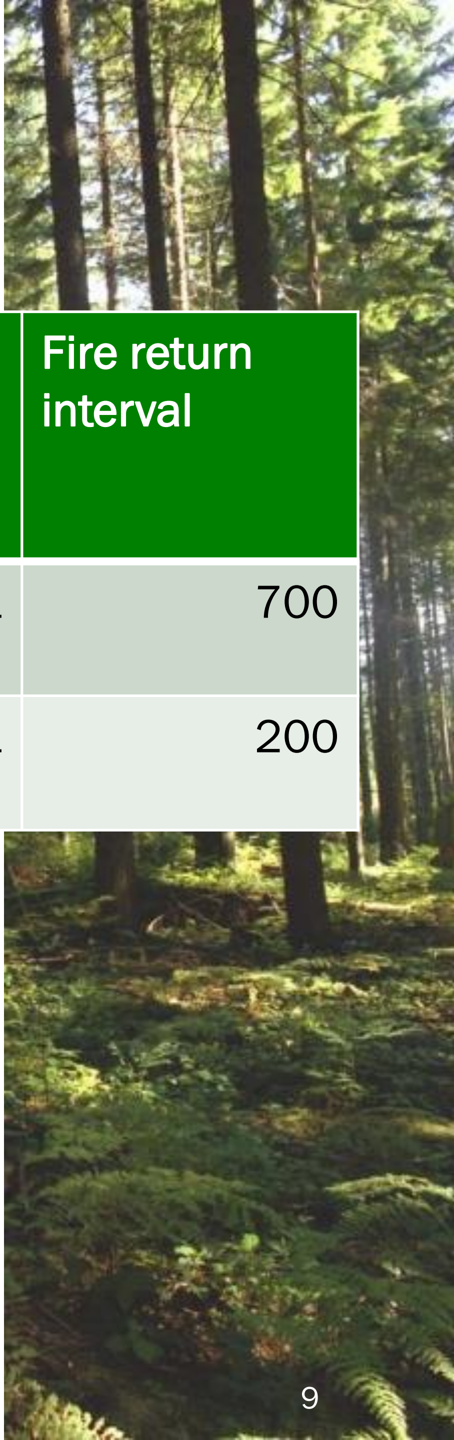
Region 7: warmest

Pinus contorta, Populous tremuloides, Picea Englemannii



Modelling regions

Region number	Dominant species	Mean annual temp (C)	Mean annual precipitation (mm)	Fire return interval
3	Englemann spruce – Subalpine fir	1.4	1081	700
7	Pine – Aspen - Spruce	3.1	521	200



Methods

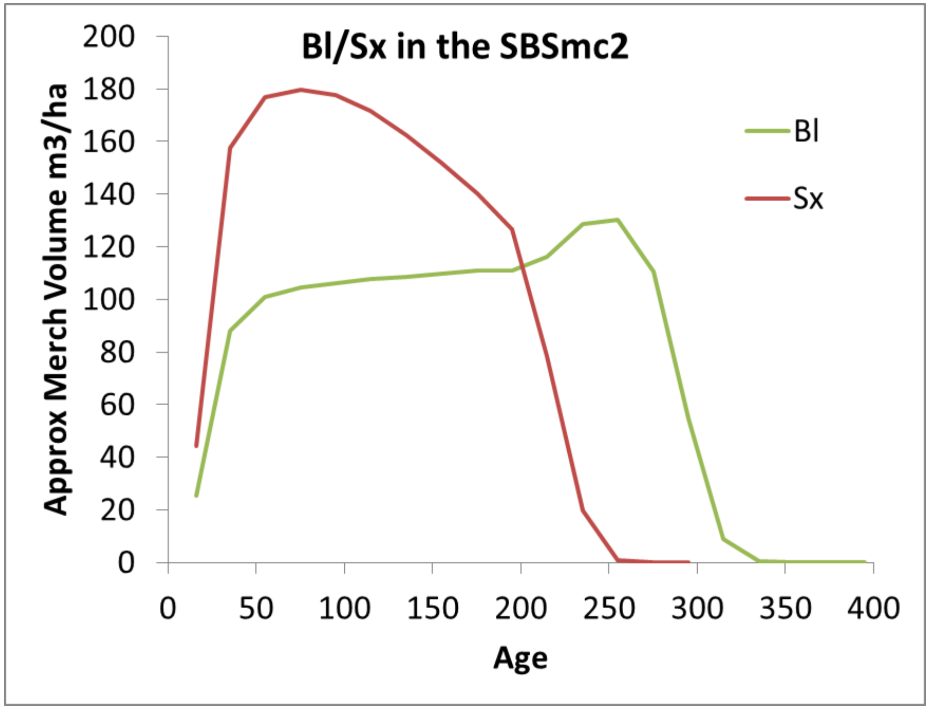
- Simulation model of forest ecosystem 2012 – 2050.
- Aggregation/ensemble of climate change projections (5 different possible futures).
- Scenarios:
  - No climate change
  - Average productivity
  - High productivity – average plus 1 standard deviation
  - Low productivity – average minus 1 standard deviation

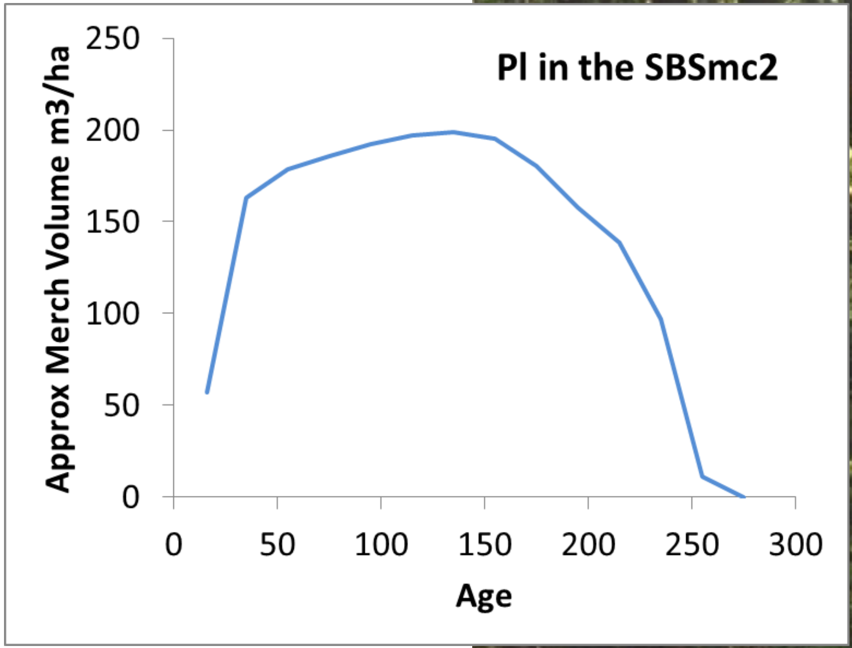
Forest landscape simulation

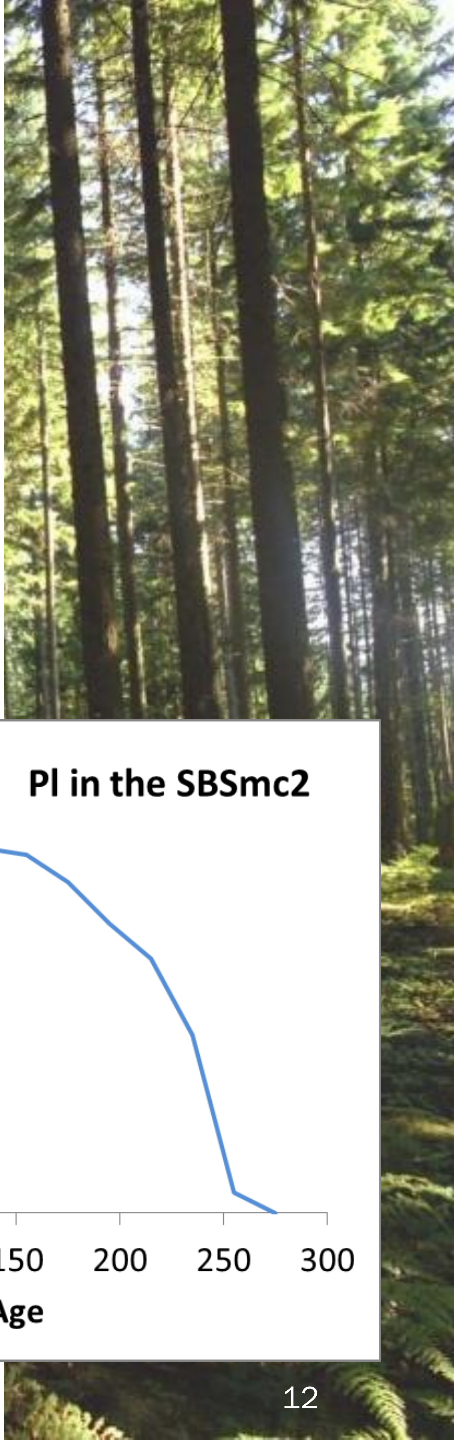
- LANDIS-II → spatial dynamic forest landscape simulation model including the Forest Carbon Succession extension.
  – Carbon stocks and fluxes are tracked over time
  – Harvest and planting regimes
  – Fire dynamics
  – 2012 – 2050

Credibility

- Biomass dynamics at a "stand-scale" checked by local experts & compared with TIPSY.
- Carbon stocks and fluxes compared with published values.

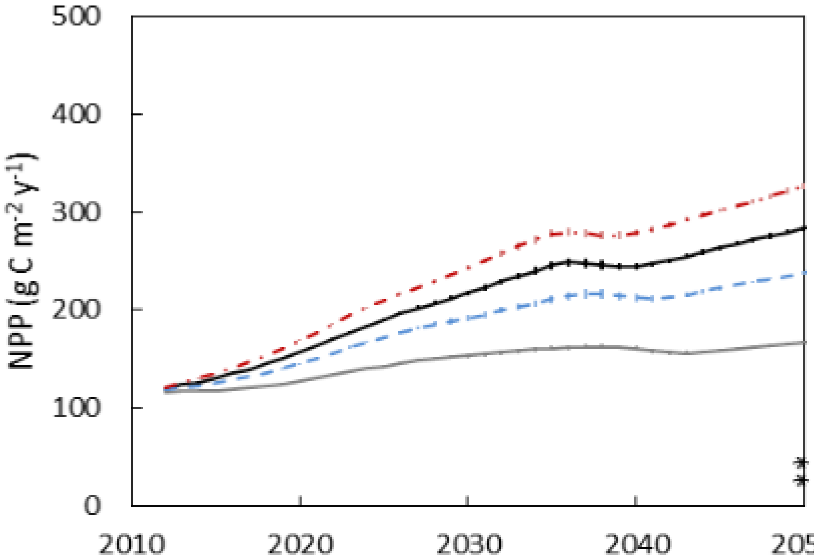






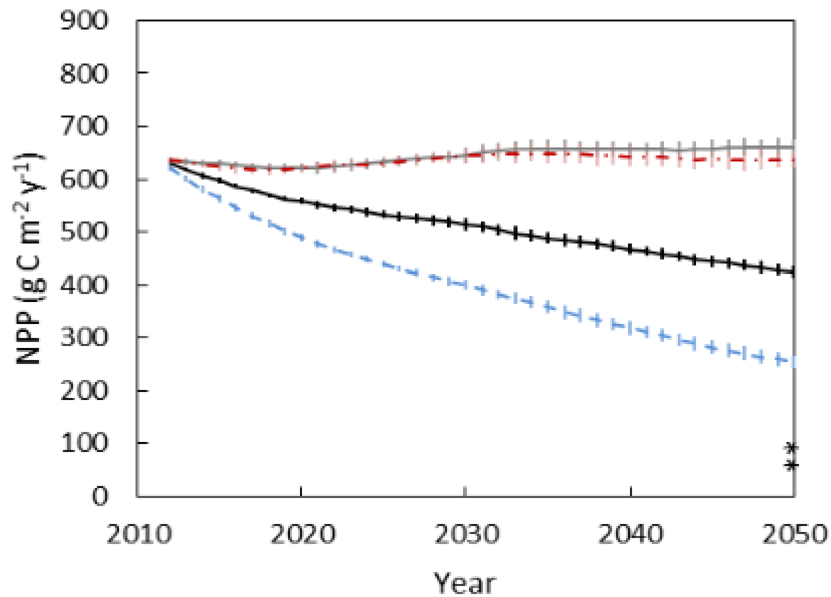
Results – landscape average productivity

Region 3 Spruce – Subalpine fir

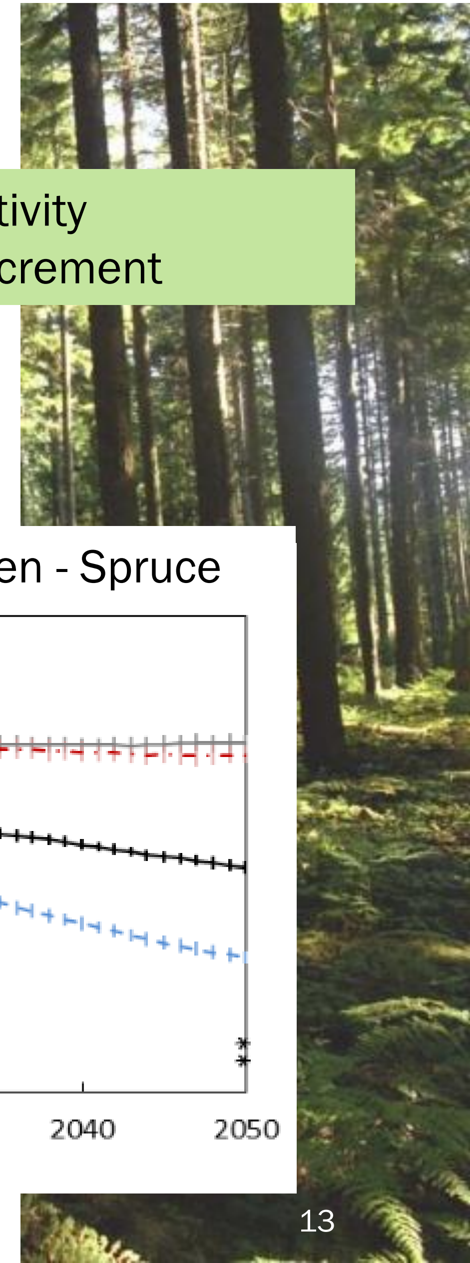


- Net Primary Productivity
- Similar to annual increment

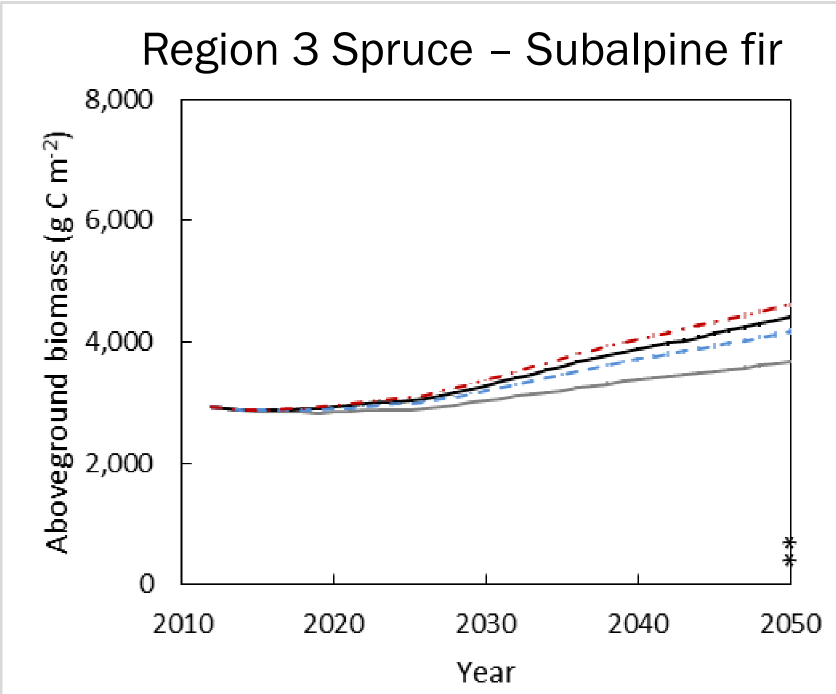
Region 7 Pine – Aspen - Spruce



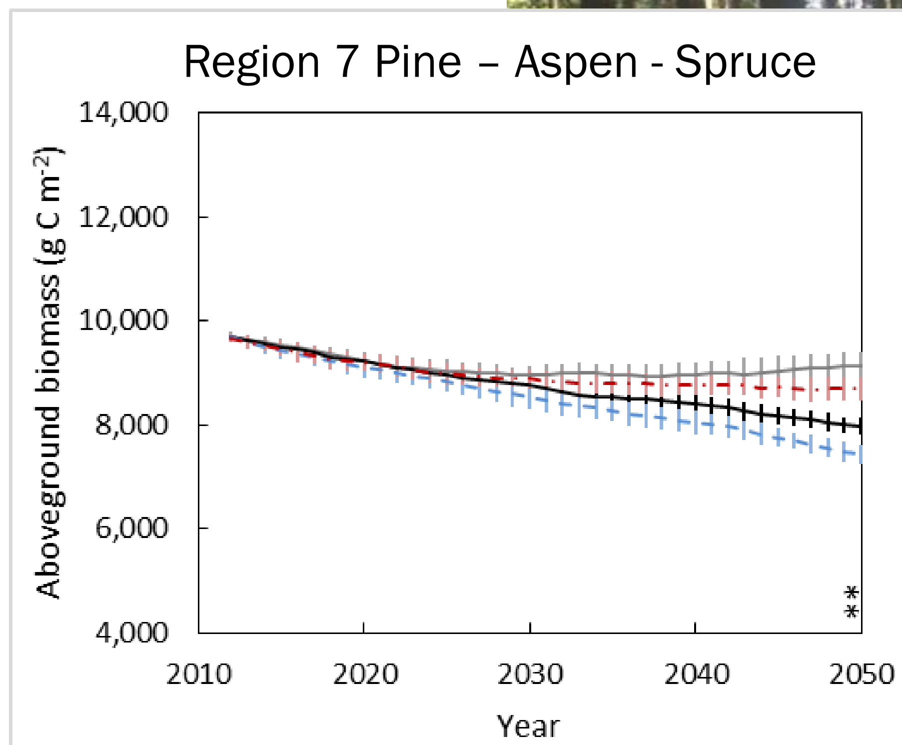
No climate change baseline
Average productivity
High productivity
Low productivity



Results – landscape average aboveground biomass

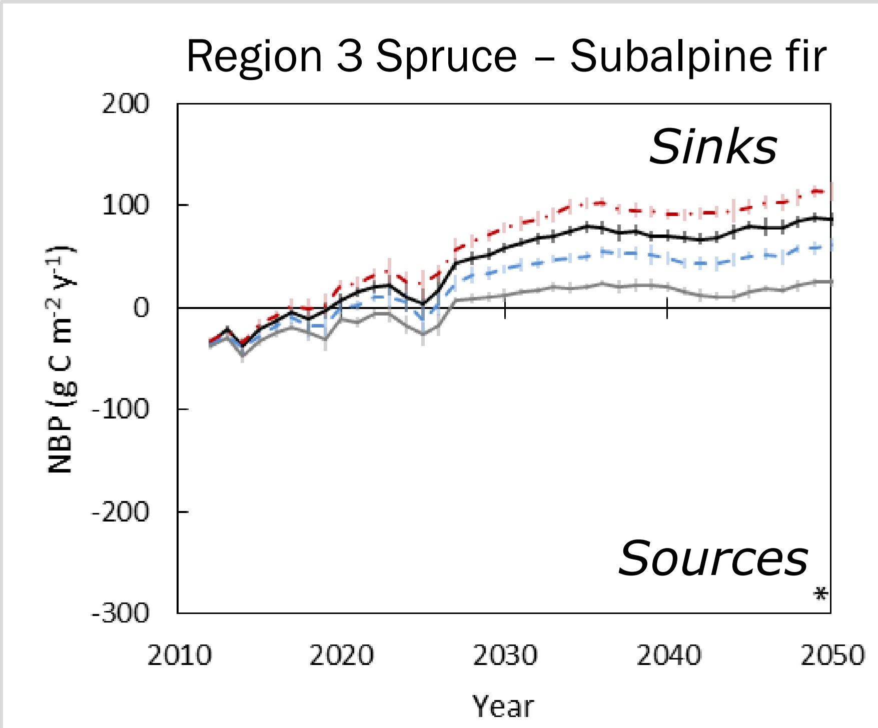


- Similar to growing stock

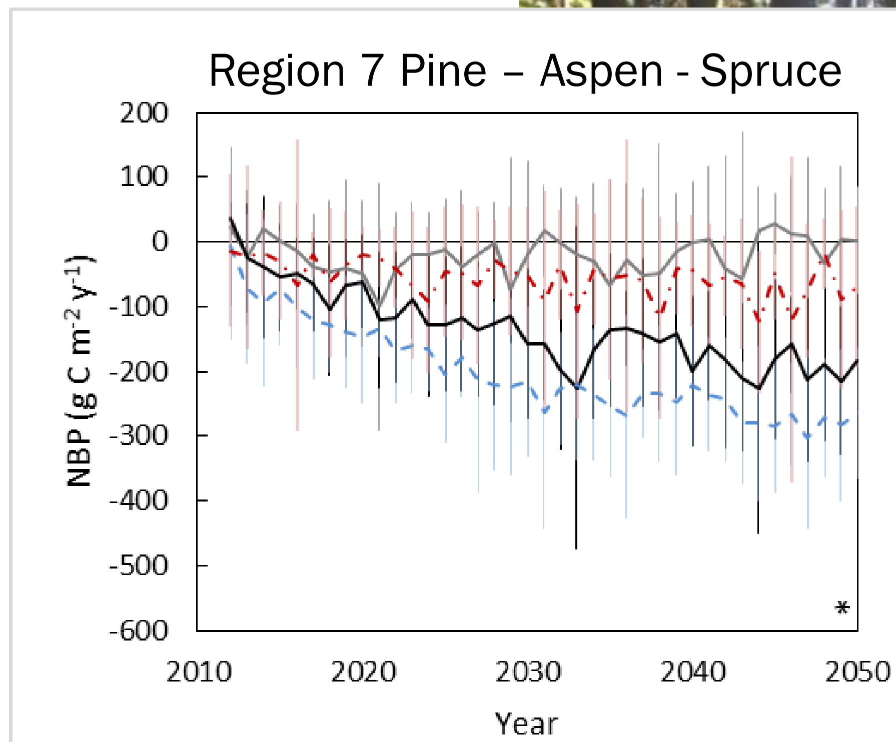


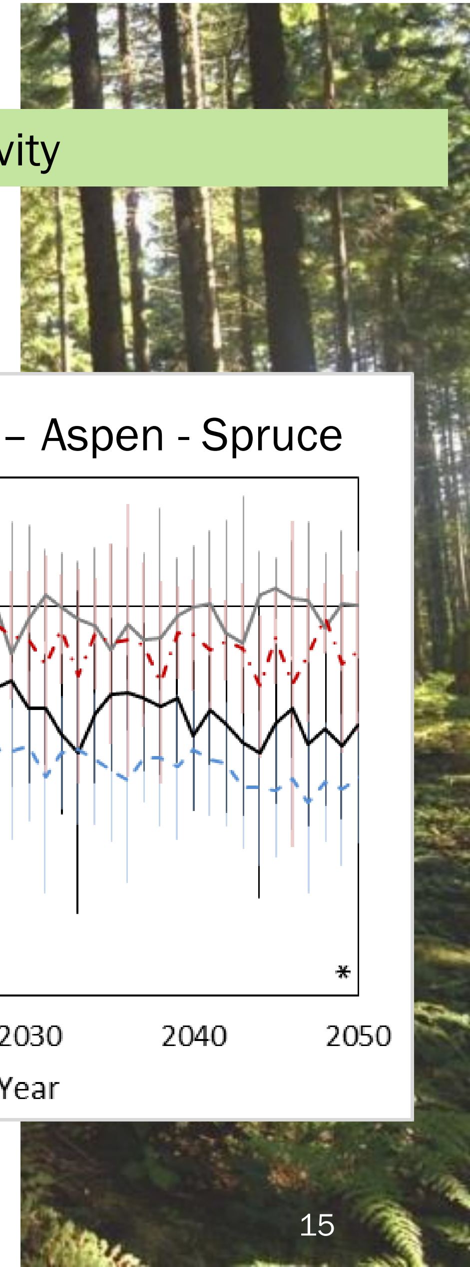
No climate change baseline
Average productivity
High productivity
Low productivity

Results – Carbon Balance



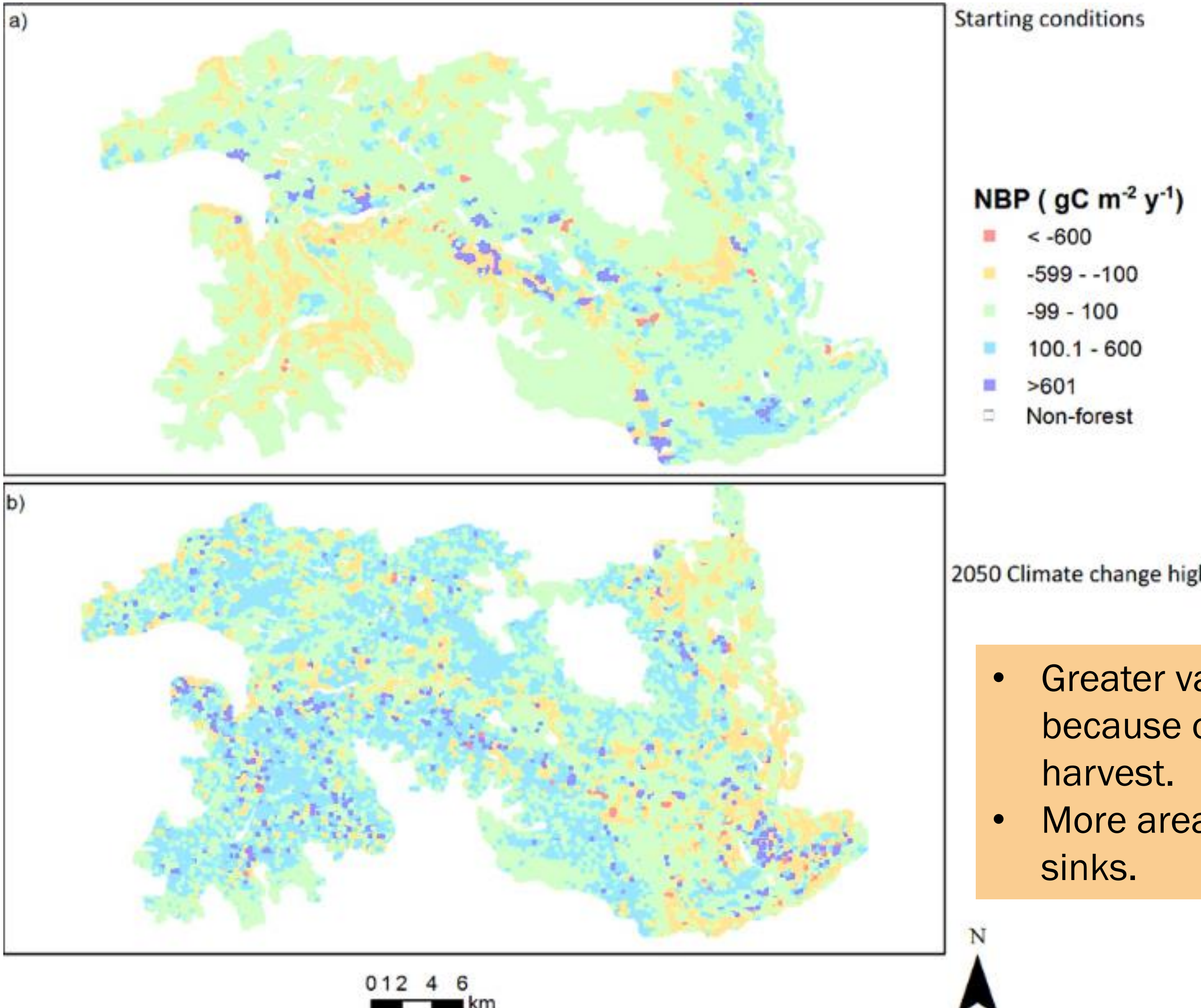
- Net Biome Productivity





No climate change baseline
Average productivity
High productivity
Low productivity

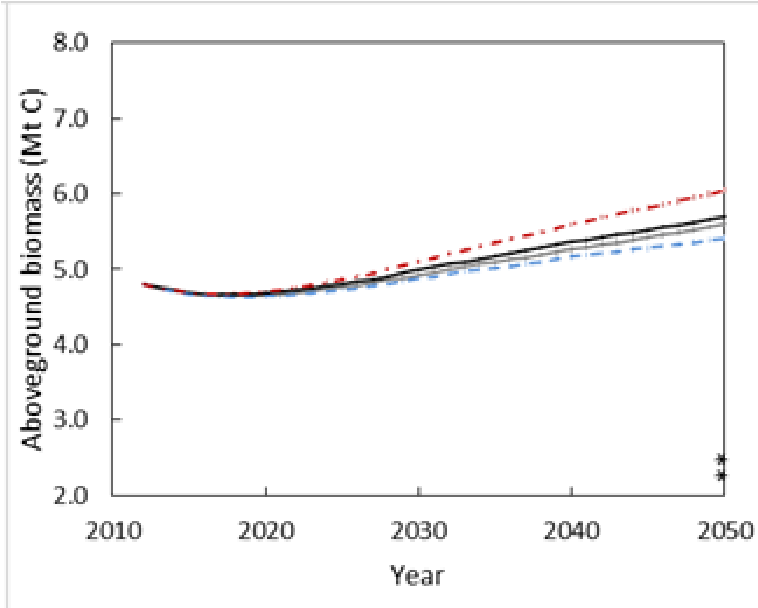
Results – Carbon balance = Net Biome Productivity



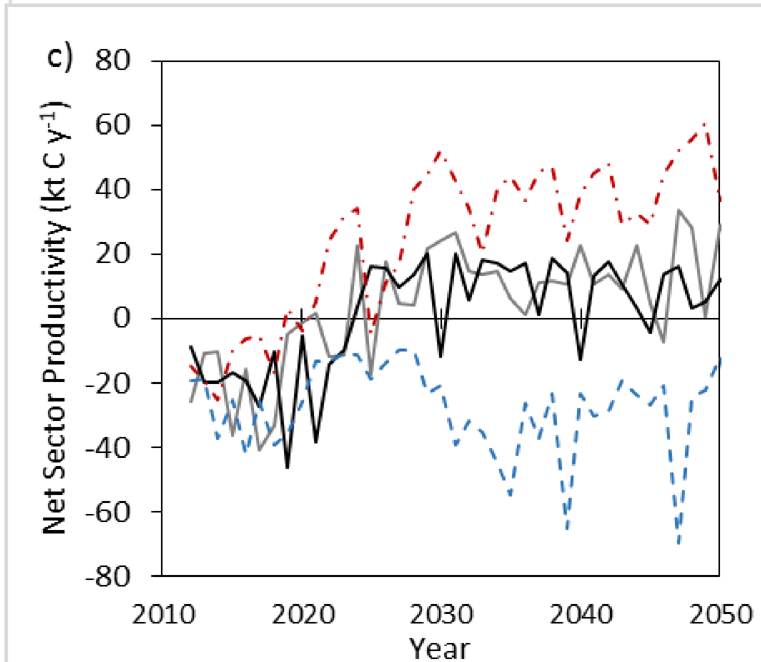
- Greater variability because of fires & harvest.
- More area in carbon sinks.

Results – whole landscape

Aboveground biomass

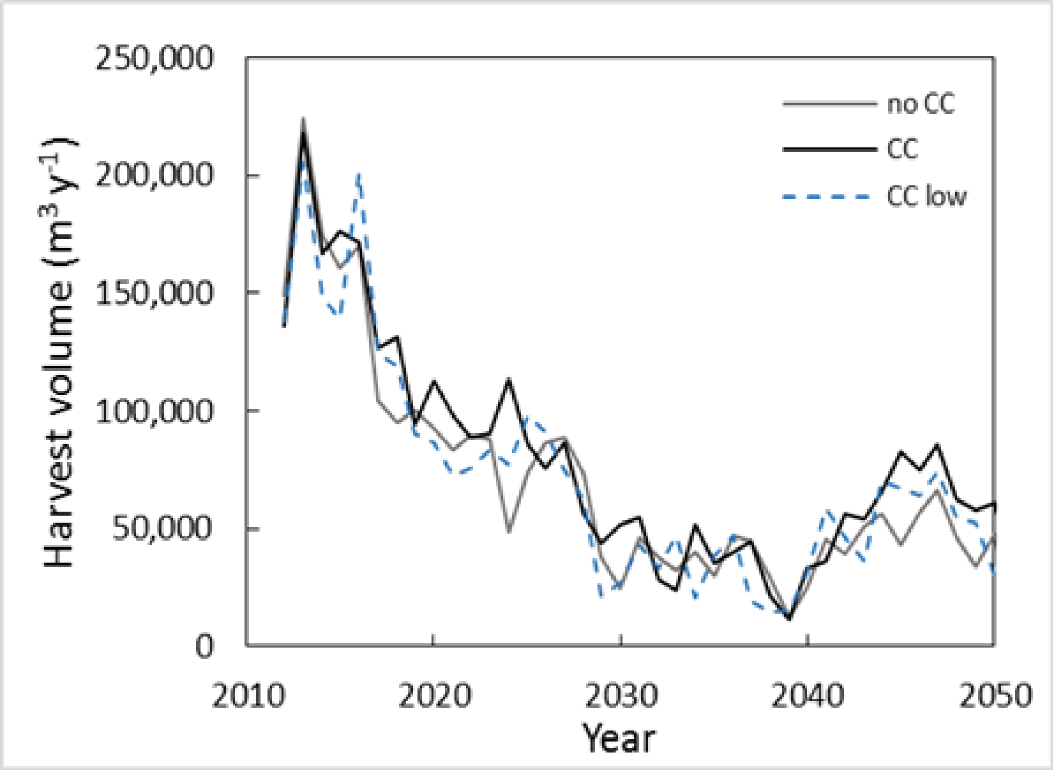


- No climate change
- Average productivity
- High productivity
- Low productivity



Net Sector Productivity = NPP
– Rh
– disturbance emissions
– HWP emissions

Results – harvest



No climate change baseline
Average productivity
High productivity
Low productivity

Harvesting mature stands

Mitigation and Adaptation Opportunities

- Add warmer-climate species to Region 7 Pine – Aspen – Spruce.
  - e.g. Douglas-fir

- Possibly increase harvest rate in Region 3 Spruce – Subalpine fir.

Summary

- Ensemble average: Lower productivity areas improved as carbon sinks.
  - But it was not enough to counter the poorer outcomes for carbon sinks & sources higher productivity areas.
  - Species moving away or toward optimum conditions.
- Large risk – how can we manage?
- Phase 2 – management options

For more information:
Carbon sequestration in managed temperate coniferous forests under climate change
www.biogeosciences.net/13/1933/2016/

Questions/poll

- Given these different effects of climate change, what forest management options would you like assessed?
  - Partial harvesting
  - Shorter rotations
  - Longer rotations
  - Different planting regimes

Part 2: Testing novel planting regimes to adapt and mitigate climate change

Climate change mitigation strategies

- Adaptation of forest management:
  - Positive
  - Negative
- Planting alternative tree species:
  - Effects on carbon pools largely unknown
  - Carbon storage depends on tree species

Aim

- Simulating the impacts of different planting regimes and climate change scenarios on:
  - Carbon pools
  - Carbon sinks/sources
  - Tree species diversity
  - Harvest levels

How can we manage natural risks?

- Ecological resilience theory

- Resilience: "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks*." Walker et al. 2004

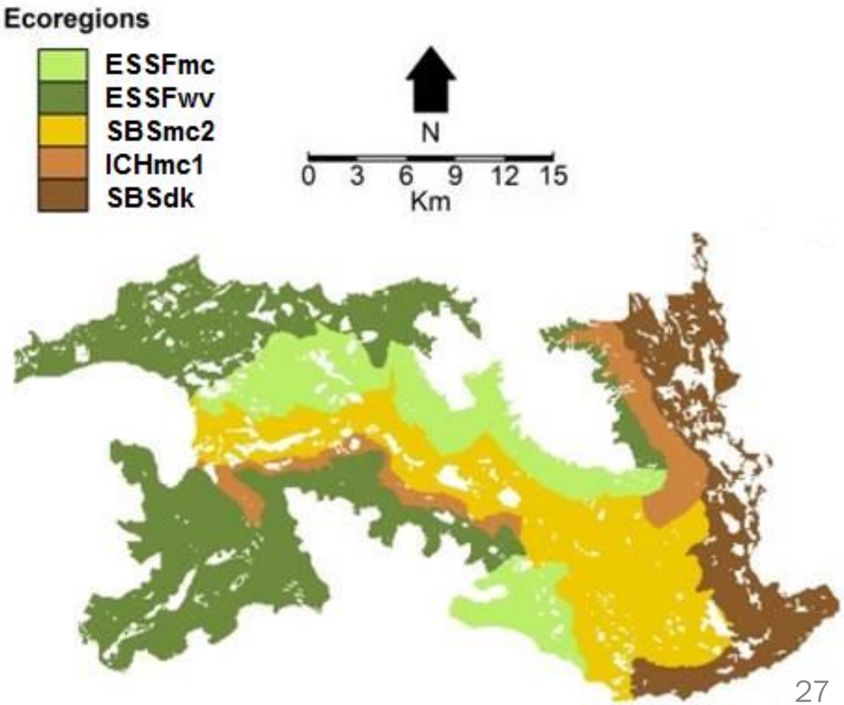
- **Ecological resilience and complexity: a theoretical framework for understanding and managing British Columbia's forest ecosystems in a changing climate**
- Campbell et al. 2009

Resilience & Species diversity

- Insurance hypothesis:
  - Greater species diversity reduces the impacts of disturbances.
  - Increases and buffers productivity.

Study region

- Copper-pinecreek: 734 km^2
- Dominated by coniferous trees
- Largely unharvested
- Mostly > 100 years old
- Transition zone: coastal and continental climates meet
- 5 distinct modelling regions



Forest landscape simulation

- LANDIS-II → spatial dynamic forest landscape simulation model including the Forest Carbon Succession extension:
  - Carbon stocks and fluxes are tracked over time
  - Harvest and planting regimes
  - Fire dynamics

  - **Mountain pine beetle**
  - **2014 – 2114**

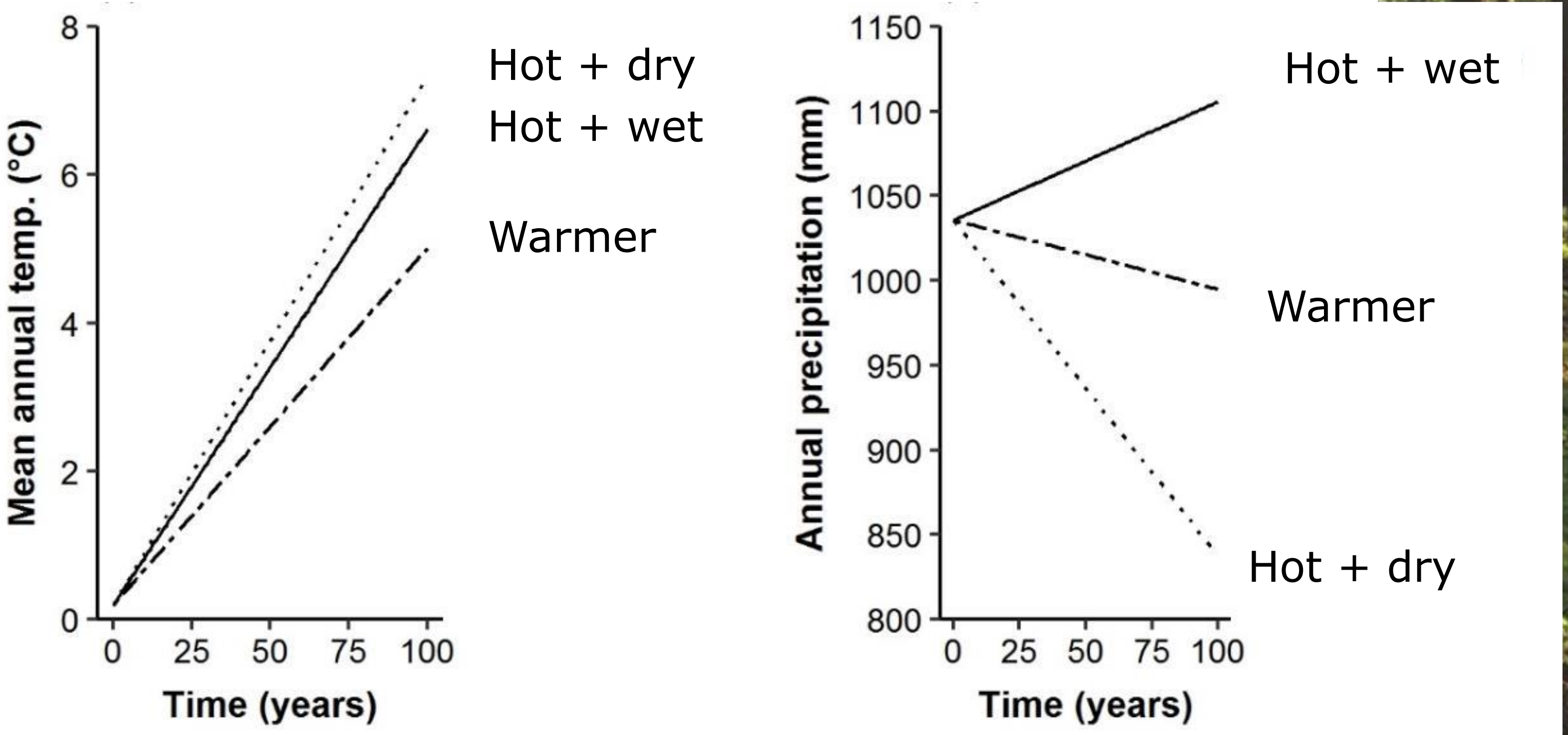
Planting regimes

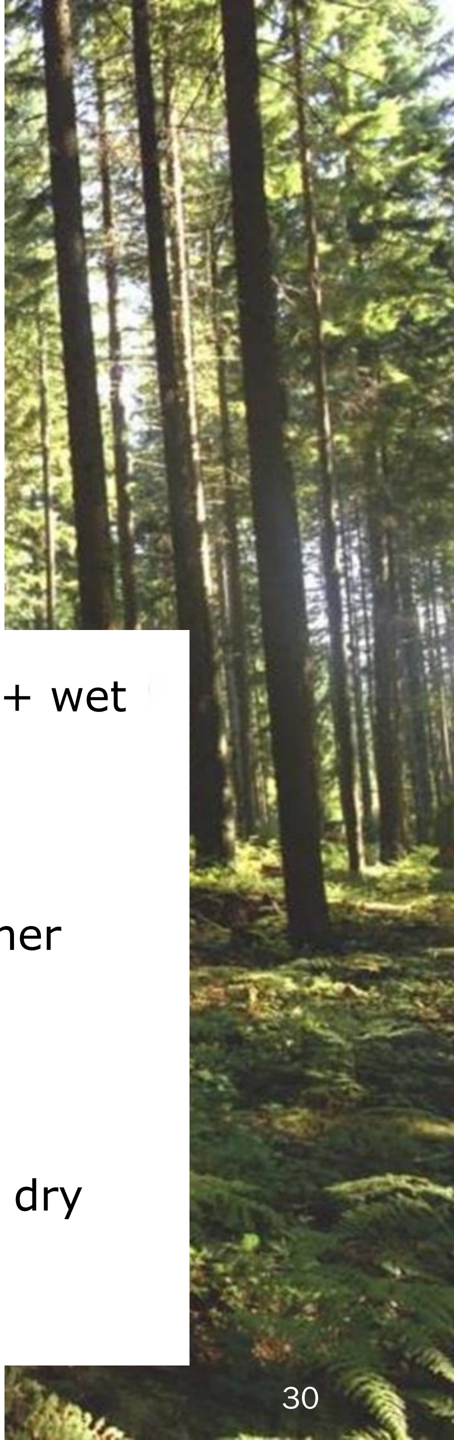
Planting strategy	Region 3 & 4 Englemann spruce – Subalpine fir	Region 5 Lodgepole pine	Region 6 Subalpine fir – Western hemlock	Region 7 Pine – Aspen - Spruce
Climate change adapted stocking standards (SS)	hybrid spruce, subalpine fir	hybrid spruce, lodgepole pine	hybrid spruce, western hemlock, subalpine fir	hybrid spruce, lodgepole pine, Douglas fir, western larch
Add Douglas fir (DF)	SS	SS + DF	SS + DF	SS
Add lodgepole pine (LP)	SS + LP	SS	SS + LP	SS
Add ponderosa pine (PP)	SS	SS + PP	SS + PP	SS + PP
Add western larch (WL)	SS	SS + WL	SS + WL	SS
Diversification	SS + DF, LP, whitebark pine	SS + subalpine fir, western hemlock, black spruce	SS + DF, LP, WL, western redcedar	SS + subalpine fir, black spruce

Climate change scenarios

Affect tree productivity depending on species and modelling region:

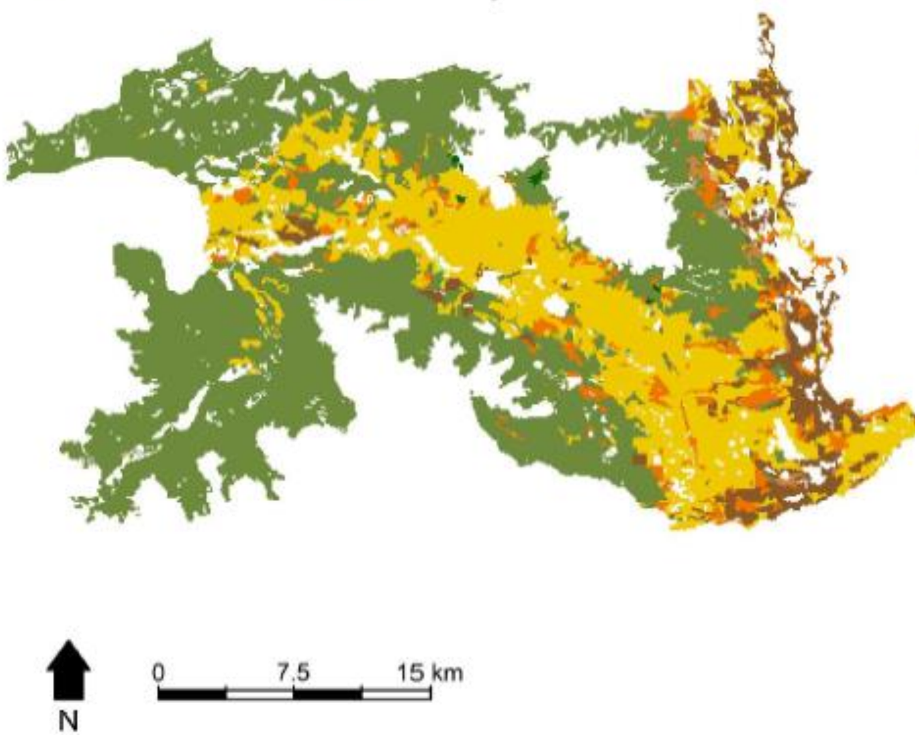
- Baseline historical climate
- Hotter and wetter (HADCM3 A1B)
- Warmer, about the same precipitation (CGCM3 A2)
- Hotter and drier (HADGEM A1B)



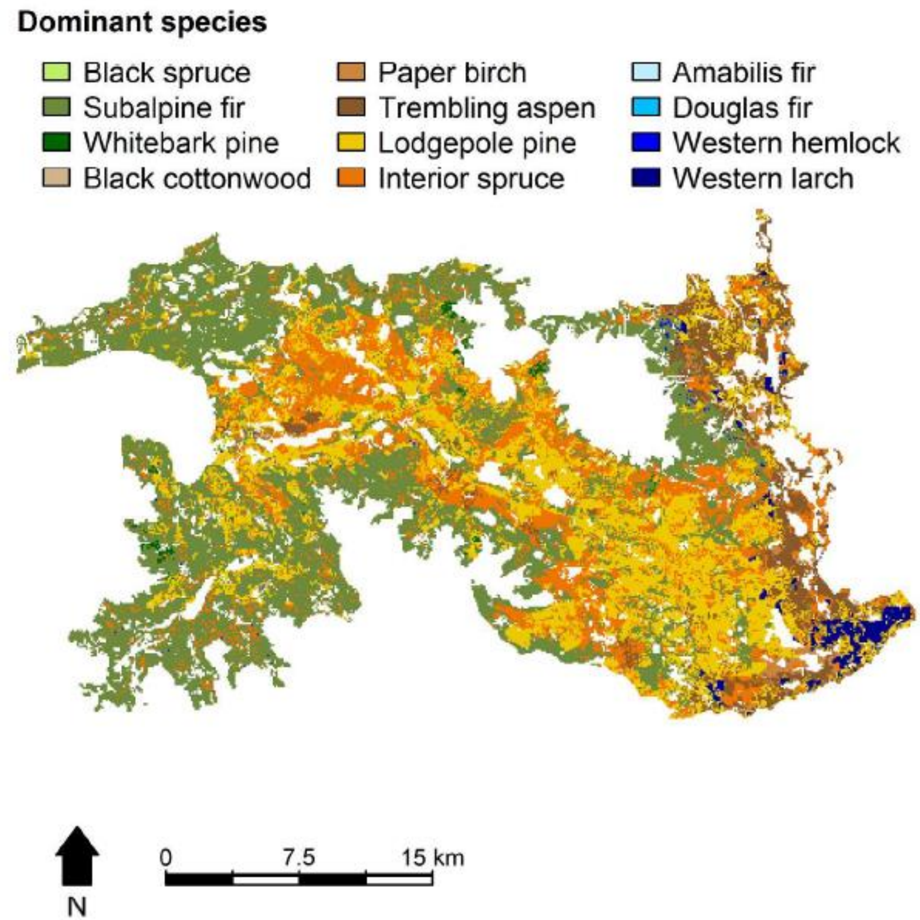


Results: Leading species under Stocking standards

Year 0

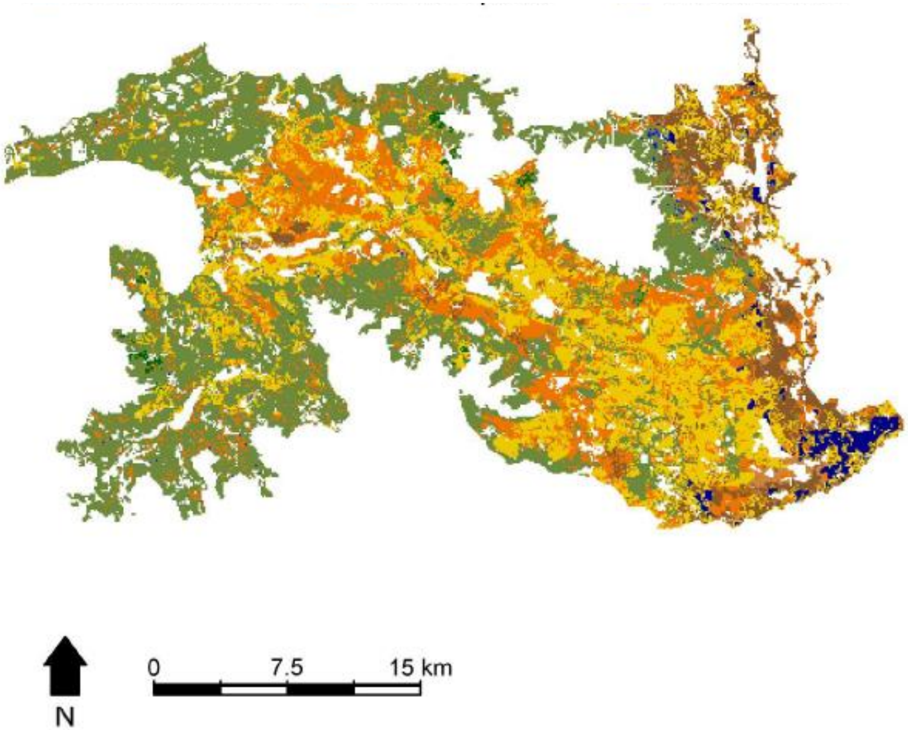


Year 100

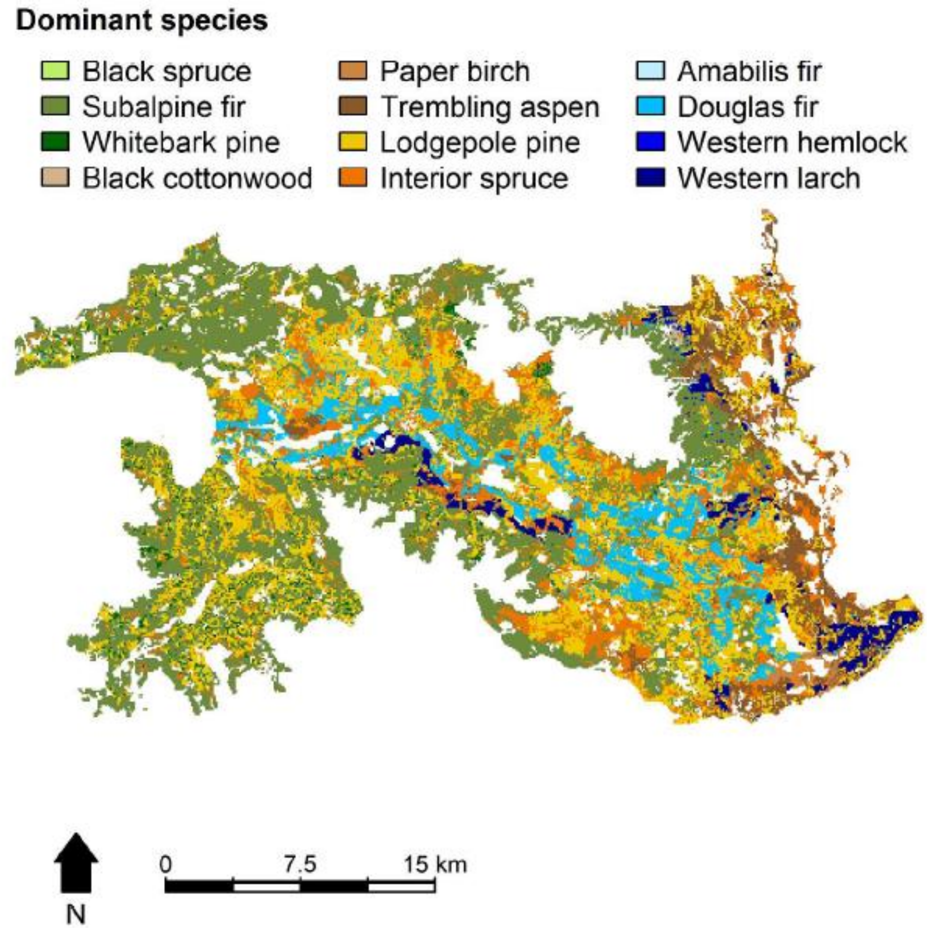


Stocking standards vs. Diversification

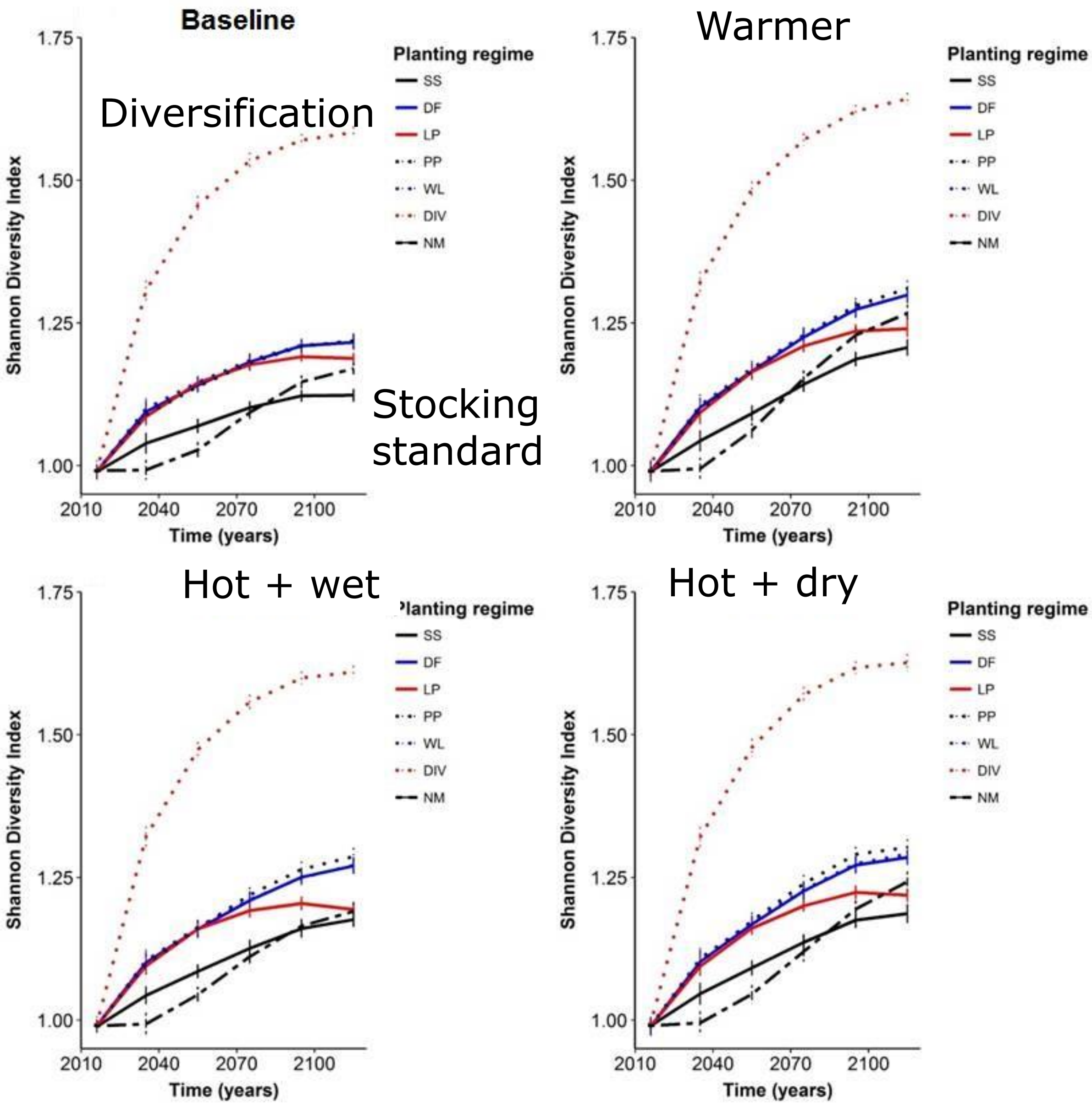
Year 100 Stocking standards



Year 100 Diversification

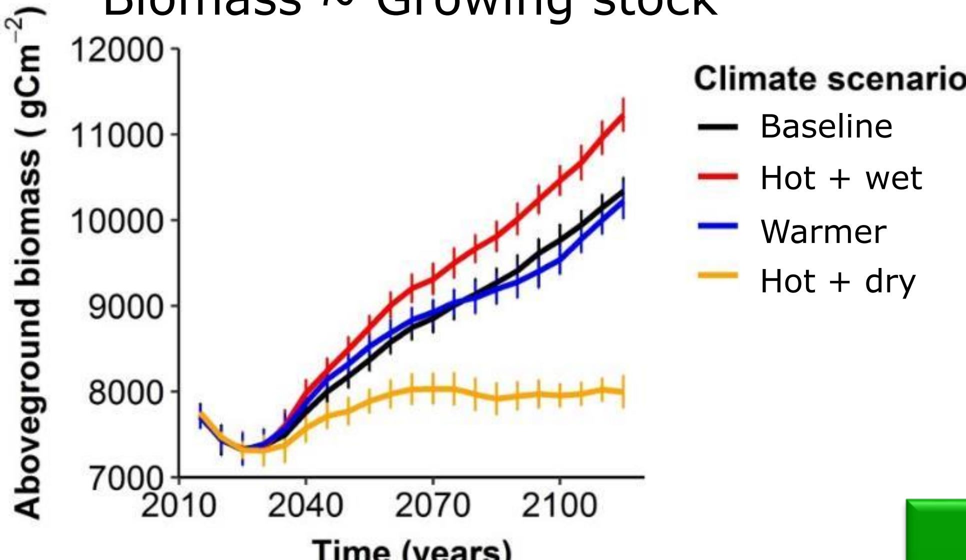


Species diversity

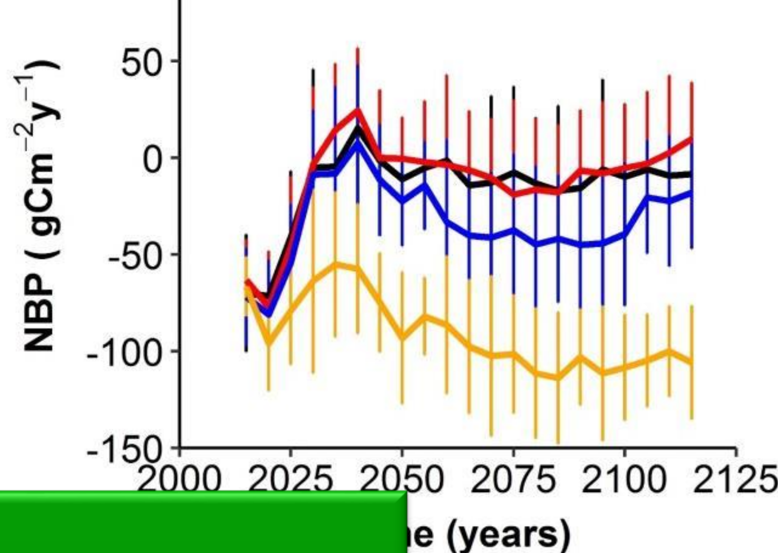


Productivity per climate scenario

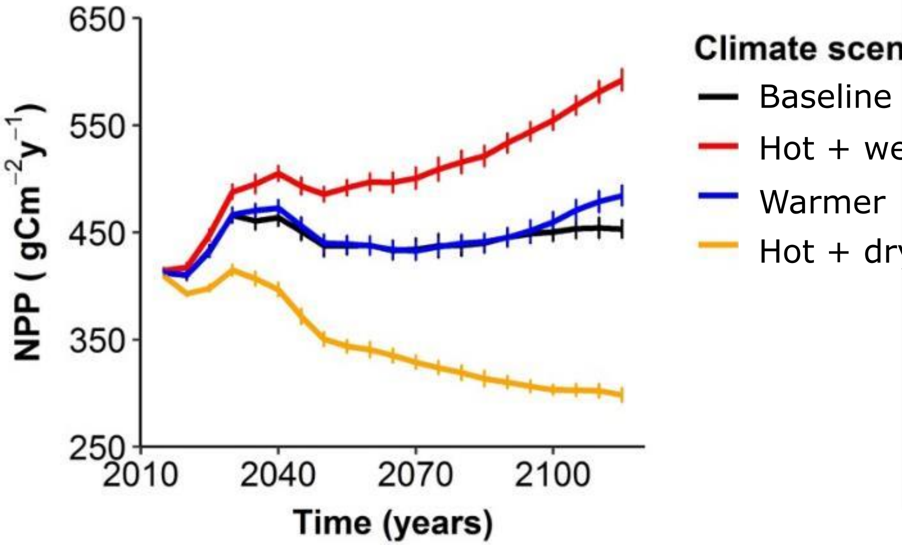
Biomass ~ Growing stock



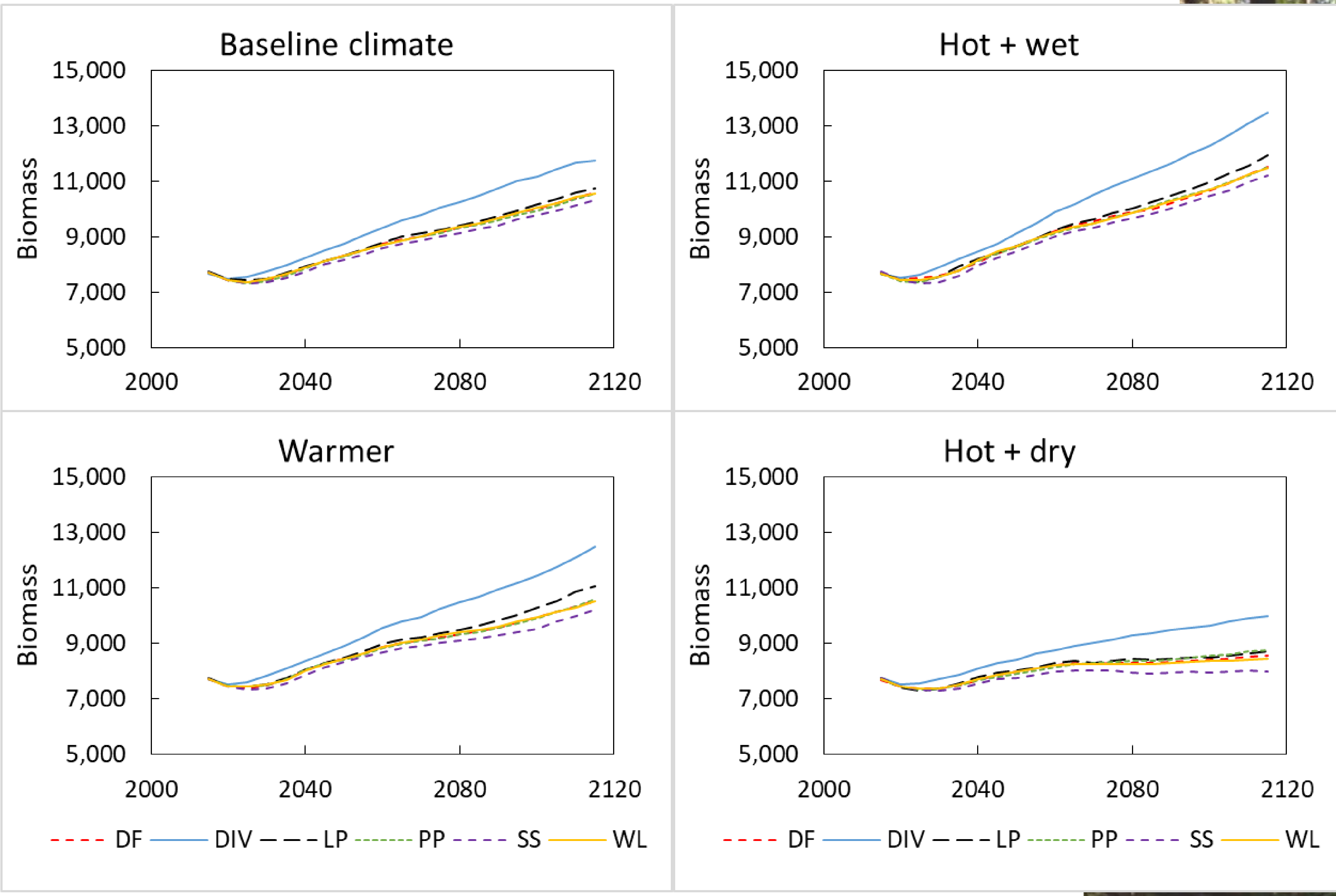
Carbon balance



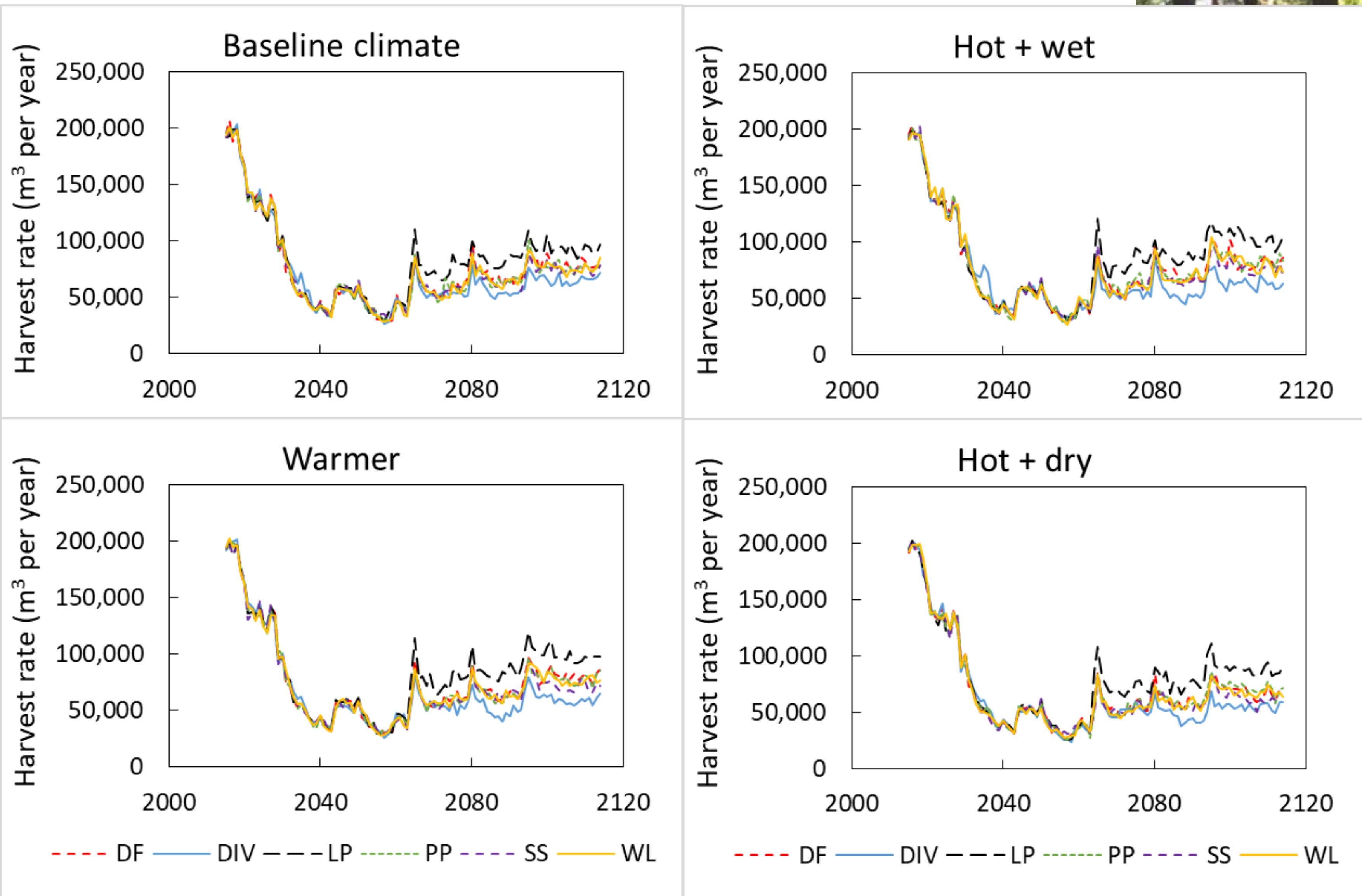
Primary productivity ~ Growth rates



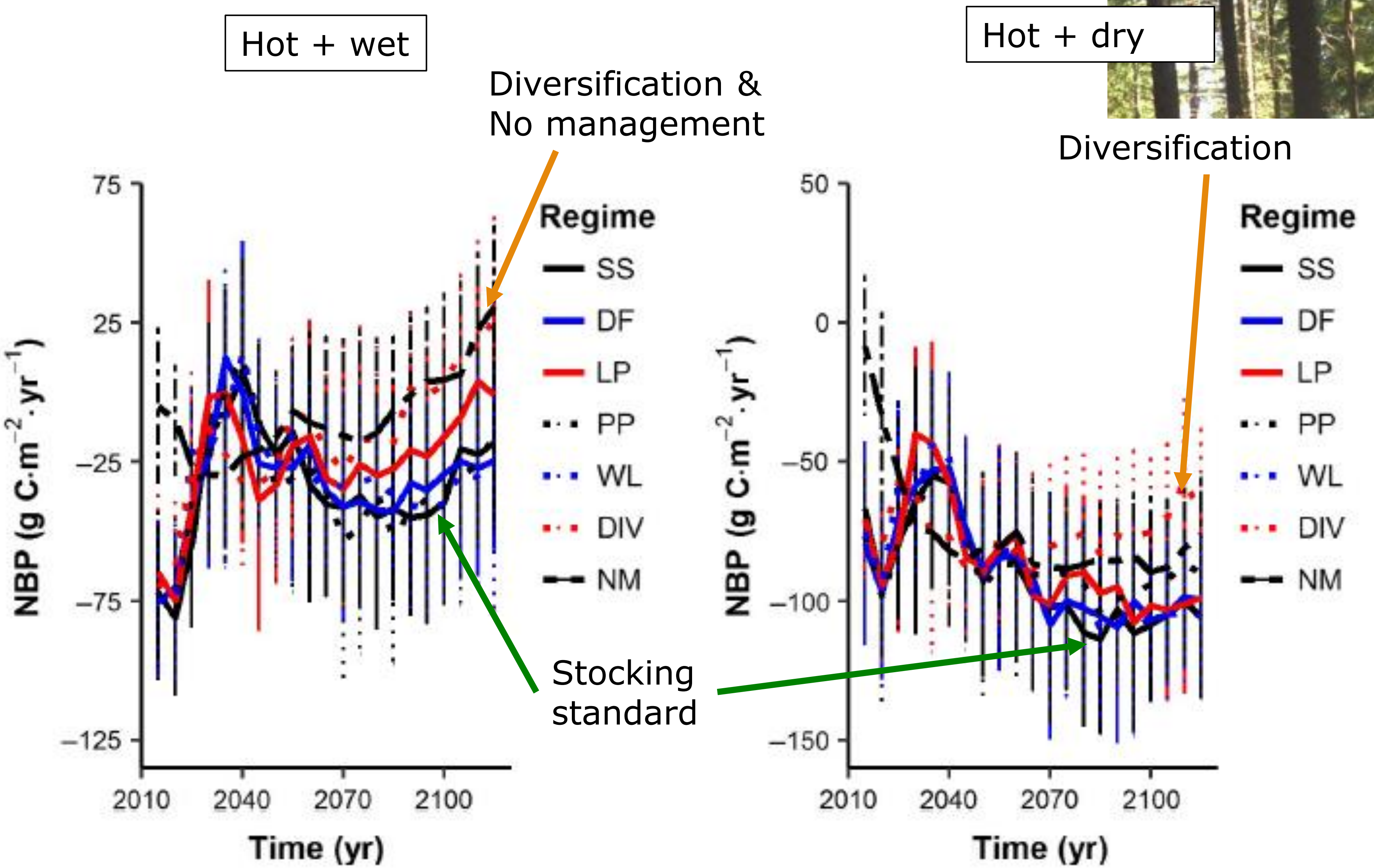
Planting regime affect on biomass



Planting regime affect on harvest

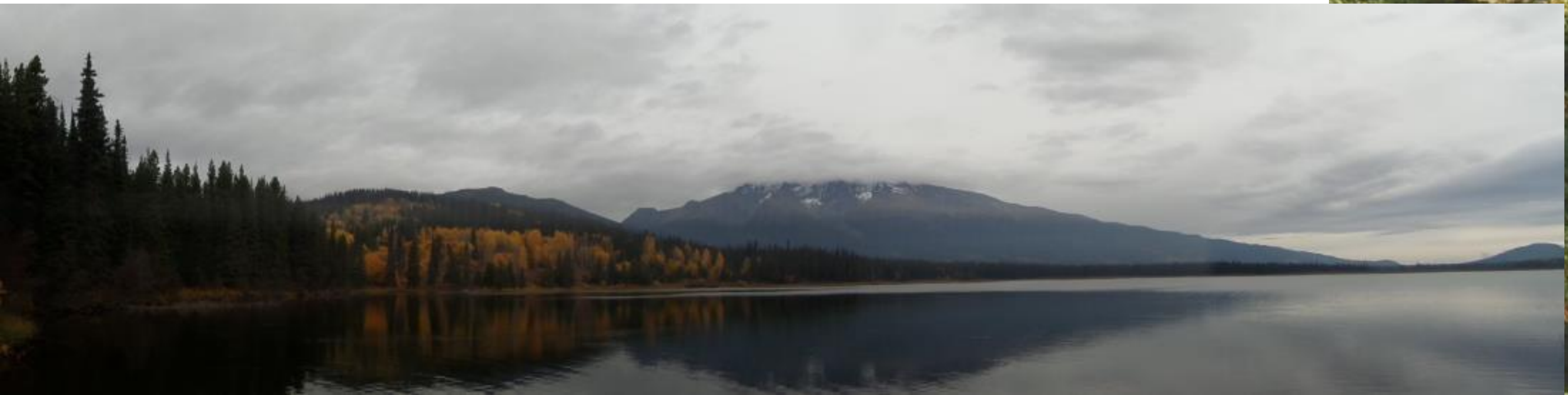


Planting regime affect on carbon balance



Conclusions

- Future productivity depends largely on the climate scenario.
- Current stocking standards are not optimal for the indicators measured.
- Diversification planting regime had higher resilience for most ecosystem services.
- Expanded planting lodgepole pine appears good alternative, but high risk …. mountain pine beetle, snowfall, rusts, etc.



Next steps

- Economic analysis of planting scenarios.
- Silviculture affects on forest carbon stocks (Date Creek Experimental Forest).

Thanks!

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For more information:

Carbon sequestration in managed temperate coniferous forests under climate change
www.biogeosciences.net/13/1933/2016/

Climate change mitigation through adaptation: the effectiveness of forest diversification by novel tree planting regimes
Anouschka Hof, Caren Dymond and David Mladenoff
Ecosphere 2017

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