ANKLIWA-DS

WP3

Forest growth modelling, economic evaluation adaptive forest management under climate change

14.05.2024, Goc

Final Meeting

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UNIQUE forestry and land use

Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
ptble Projektträger Bundesanstalt für Landwirtschaft und Ernährung
aufgrund eines Beschlusses des Deutschen Bundestages

universität freiburg

Development and implementation of adaptation strategies to climate change in forest management

Razvoj i primena strategija prilagođavanja klimatskim promenama u gazdovanju šumama

ANKLIWA-DS

With help of …

Danyal Altunay

(Economic Model)

Hanna Blauth

(LAI measurements for model parametrization)

PE Vojvodina šume and Serbiašume for data (inventory, price lists etc)

… and of course the entire project team!

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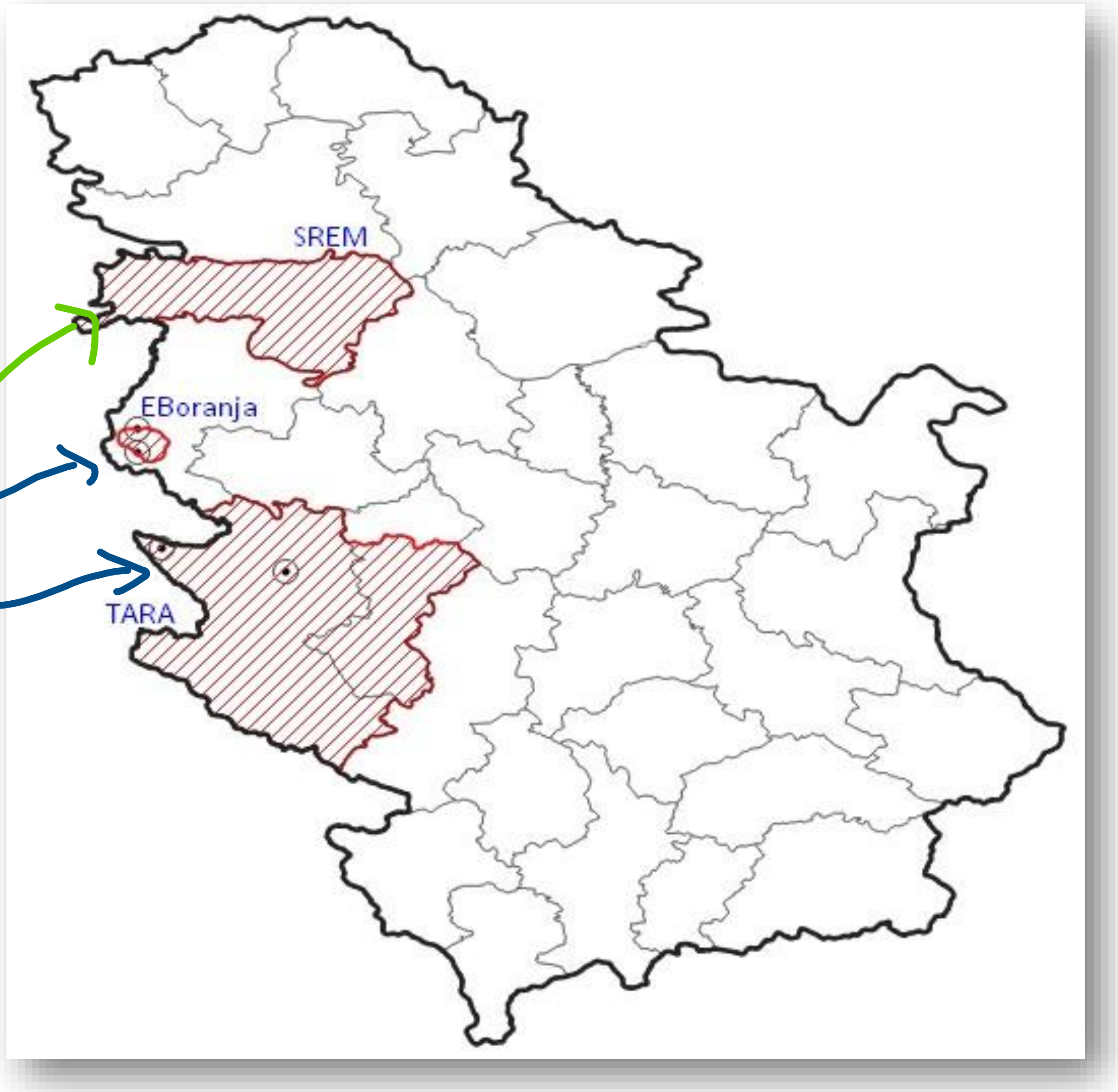
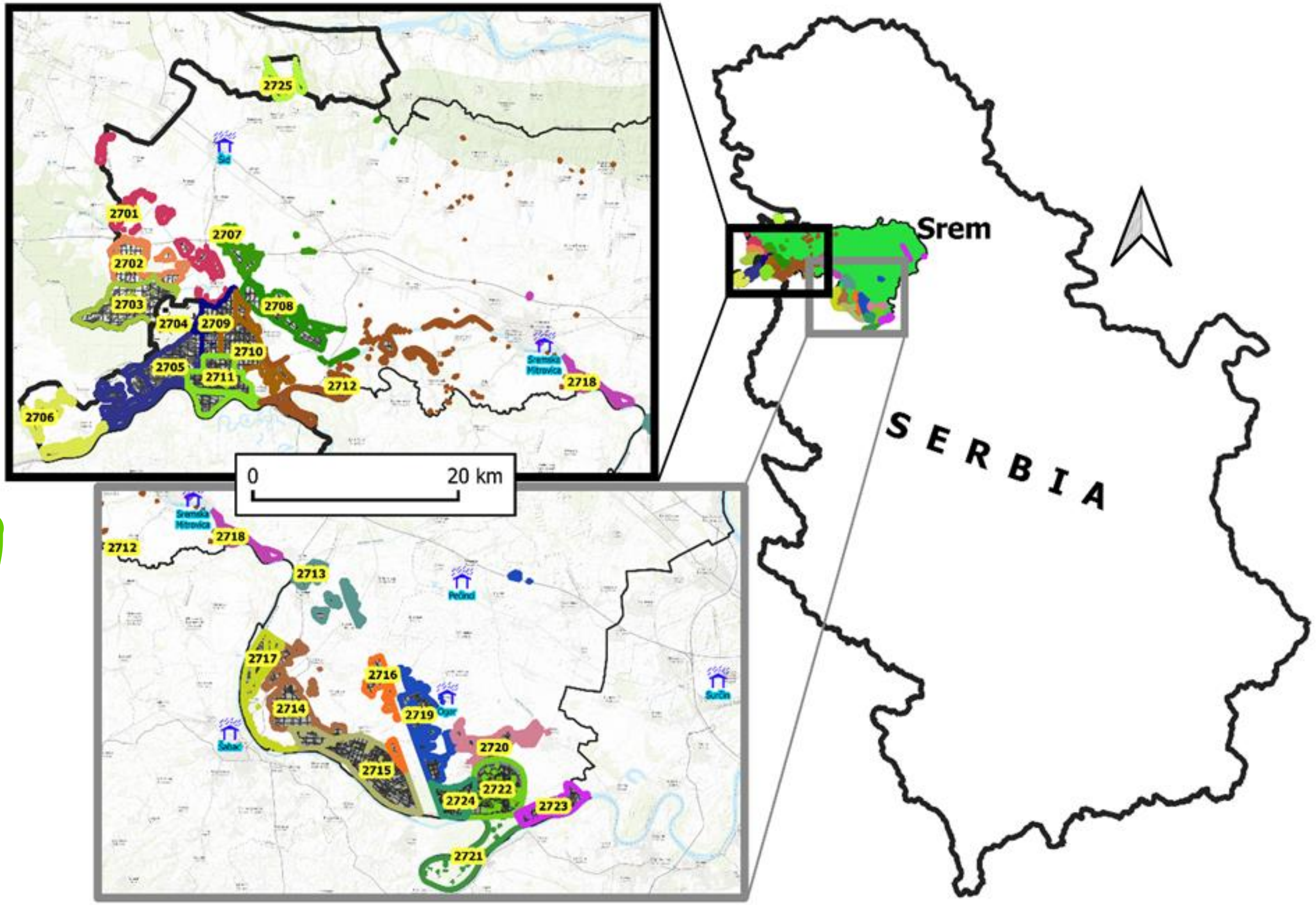
ANKLIWA-DS

Oak

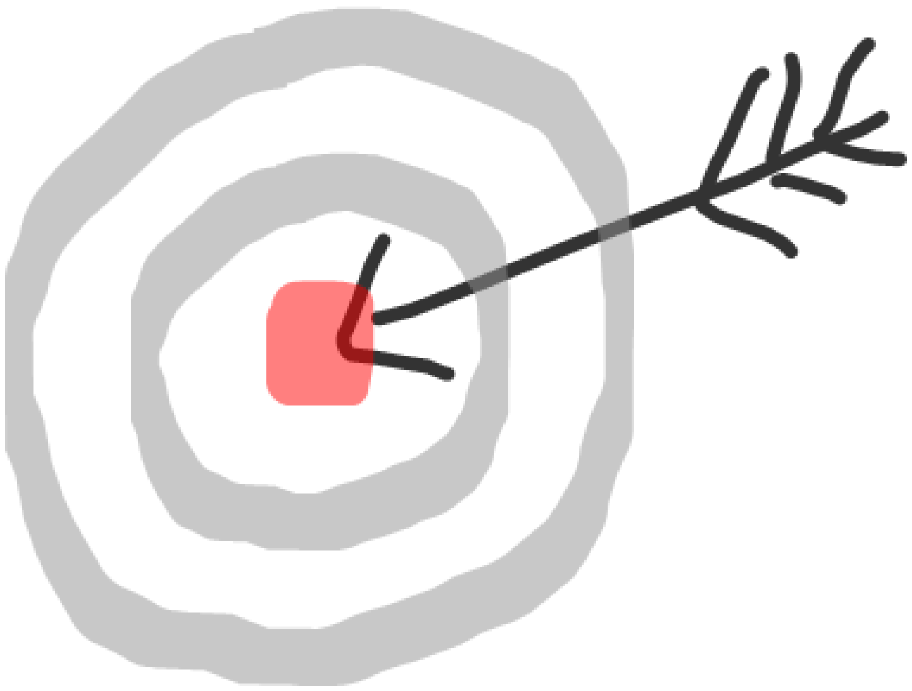
Beech

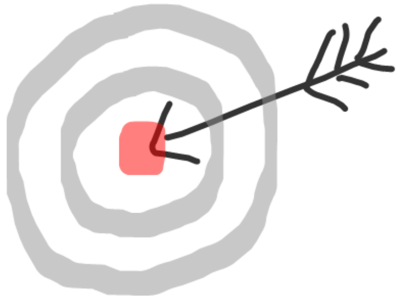




Kazimirovic et al (2024) *Annals of Forest Science*

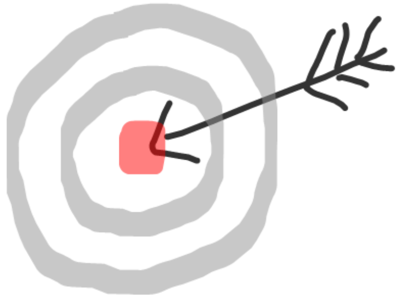
What are we doing the simulations for?





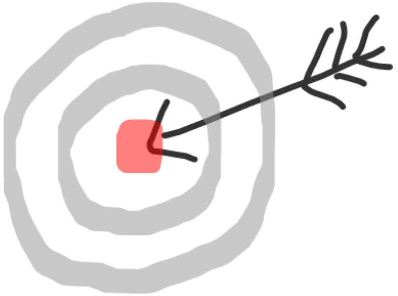
What is the impact of future climate change on forest growth and productivity?

→ The ONE climate change does not exist! Many pathways, many scenarios, lot of uncertainty.
We don't know!



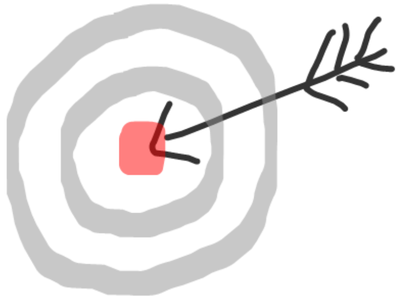
How are oak forests affected by declining groundwater levels?

→ Water availability for oak productivity in Ravni Srem is strongly dependent on river and groundwater levels – how will CC impact water availability and growth? **We don’t know!**

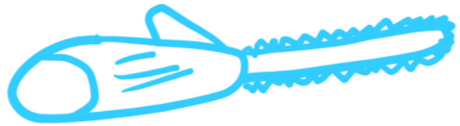


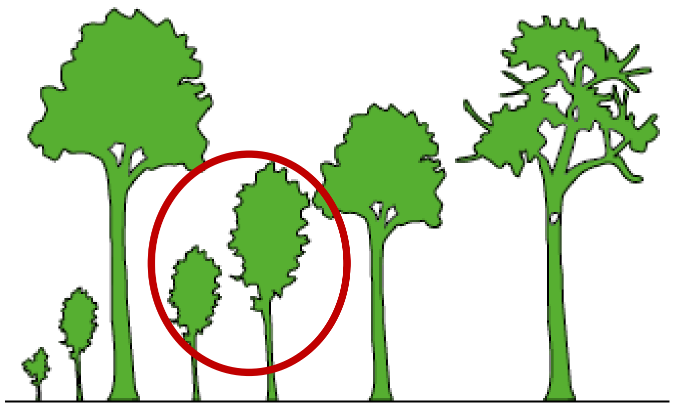
What are economic risks of CC and adaptation?

→ Future price and cost uncertainty! What will be the demand, future wood use, work etc. in the future? **We don't know!**

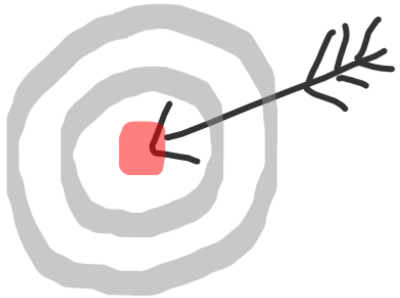


How can forest management be adapted to unknown future climate and economy?





→ Management decisions depend on consciousness, objectives and change with time. Future Plan? Best Plan? **We don't know!** Many different forest development stages - young stands in focus, still easily steerable.



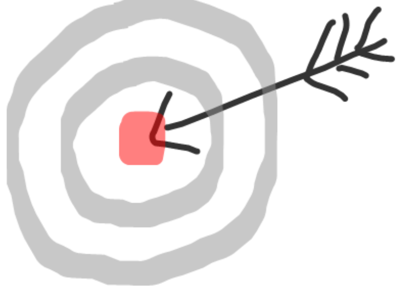
Lots of “Don’t knows” so far! Reflects the uncertainty of future possible states of the world.

Scientists don’t know the future better! We just do better and more structured guessing.

Essentially, we ask what-if questions and play through scenarios with sophisticated models.

Model results are not the reality! They are simply projections of possible states of the world based on our limited knowledge and assumptions.

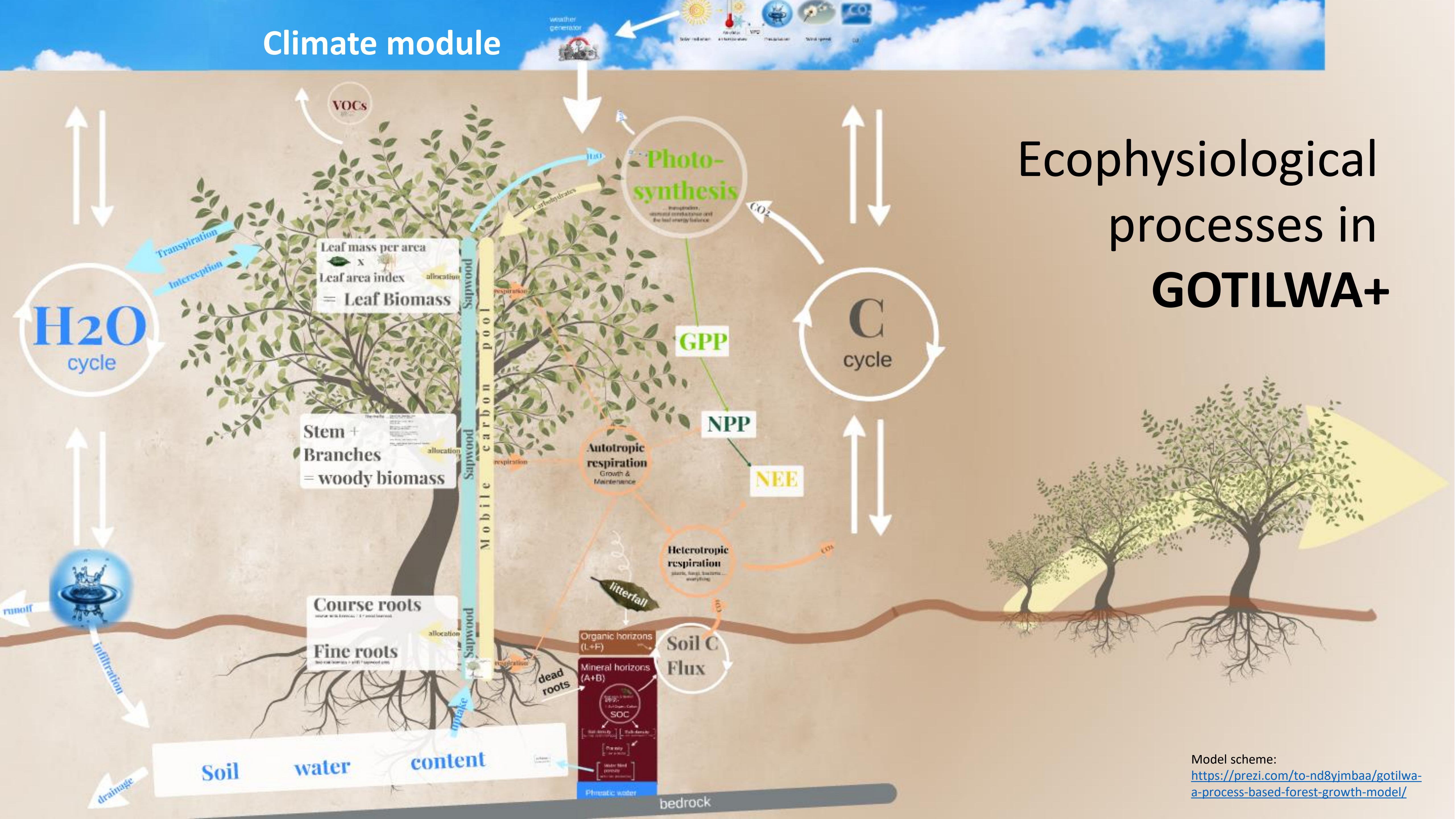
In the best case, results can be used as guidance and provide action corridors



How to tackle "don't knows" and uncertainty?

i) Employing a detailed forest growth simulator GOTILWA+
&
ii) develop and couple it with an economic model
&
iii) experiment with several management options

Ecophysiological processes in **GOTILWA+**



Model scheme:
https://prezi.com/to-nd8yjmbaa/gotilwa-a-process-based-forest-growth-model/

Here comes the structured guess work ….

Management

- Business-as-usual (BAU)
- Adjusted silvicultural guidlines – moderate (MID)
- Adjusted silvicultural guidlines – Intense (INTENSE)
- No management (NoMG)

→ 4

Climate scenarios

- No climate change (NoCC), RCP4.5 and RCP8.5
- 6 climate models each

→ 18

CO_2 fertilization effect (eCO_2)

- eCO_2 on and off

→ 2

Declining groundwater tables

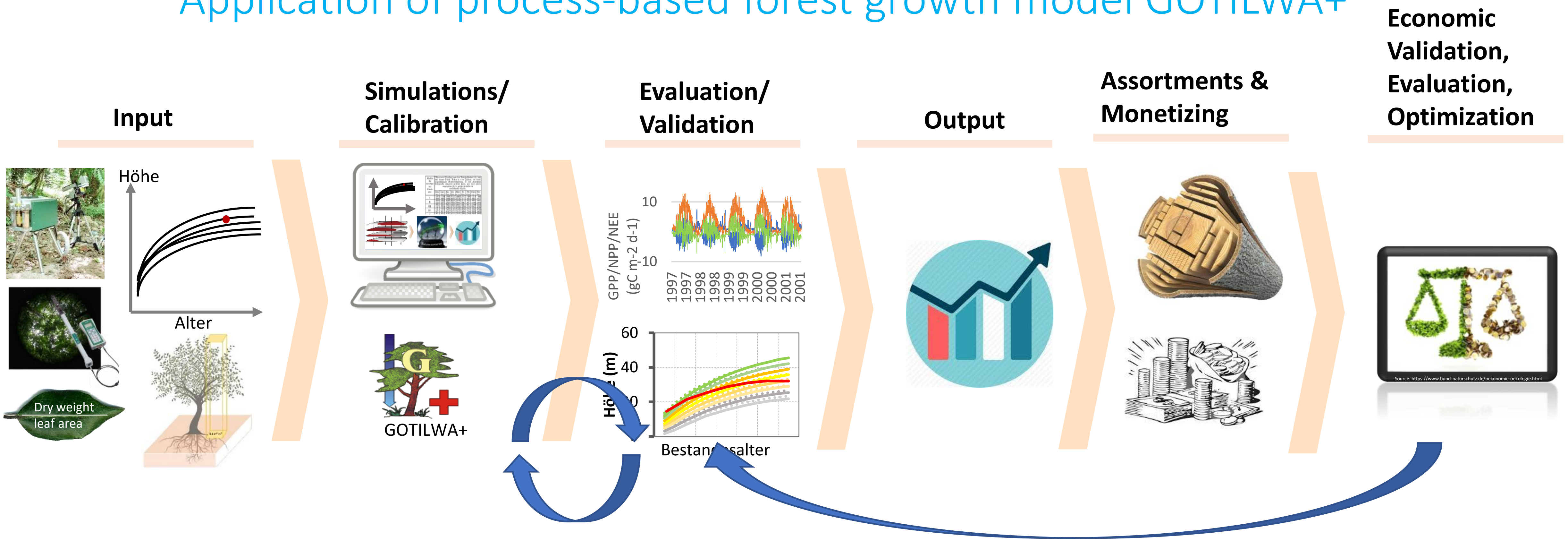
- Phreatic water uptake (PWU): 0%, 5%, 10%, 15%

→ 4

= 576 simulations

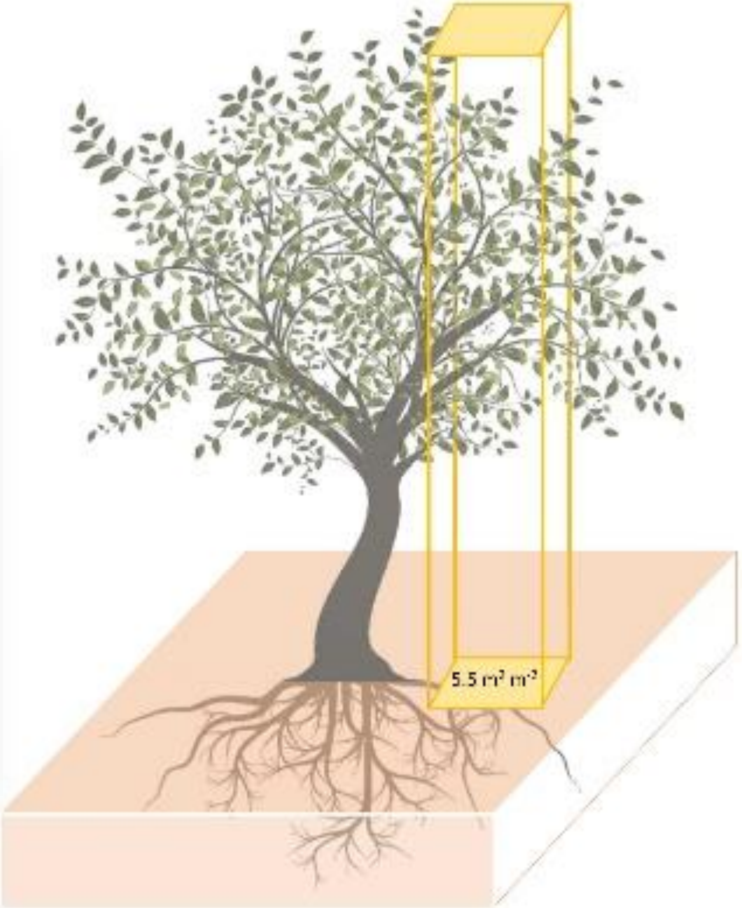
with GOTILWA+

Application of process-based forest growth model GOTILWA+



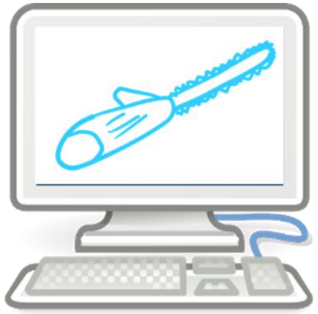
Beautiful Serbian Oak forests

LMA and LAI measurements



Leaf canopy analyser LAI2200C

Simulation Setup: Management



Harvesting volumes in m3 per ha & decade

Age class	BAU	NEW
0-10		0
10-20		10-15
20-30	10-15	65
30-40	30	80
40-50	35	80
50-60	40-50	80
60-70	40-50	80
70-80	40-50	80
80-90	40-50	60
90-100	40-50	60
100-110	40-50	60
110-120	40-50	60
120-130	40-50	Final harvest
130-140	40-50	Final harvest
140-150	40-50	
150-160	Final harvest	
sum	482	720

BAU

- Current management plans according realized yields (inventory data)

NEW

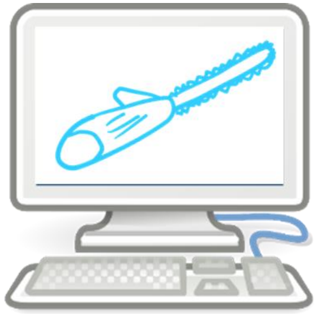
- newly developed management schedule in ANKLIWA-DS
- First draft based on Forest Developement Types of Baden-Württemberg
- Adapted in ANKLIWA-DS & with new management guidelines

In essence …

- apply higher thinning intensities
- focus on fewer future crops trees
- beginn earlier with thinnings

→ Harvesting schedules were re-calculated for GOTILWA+

Management in GOTILWA+



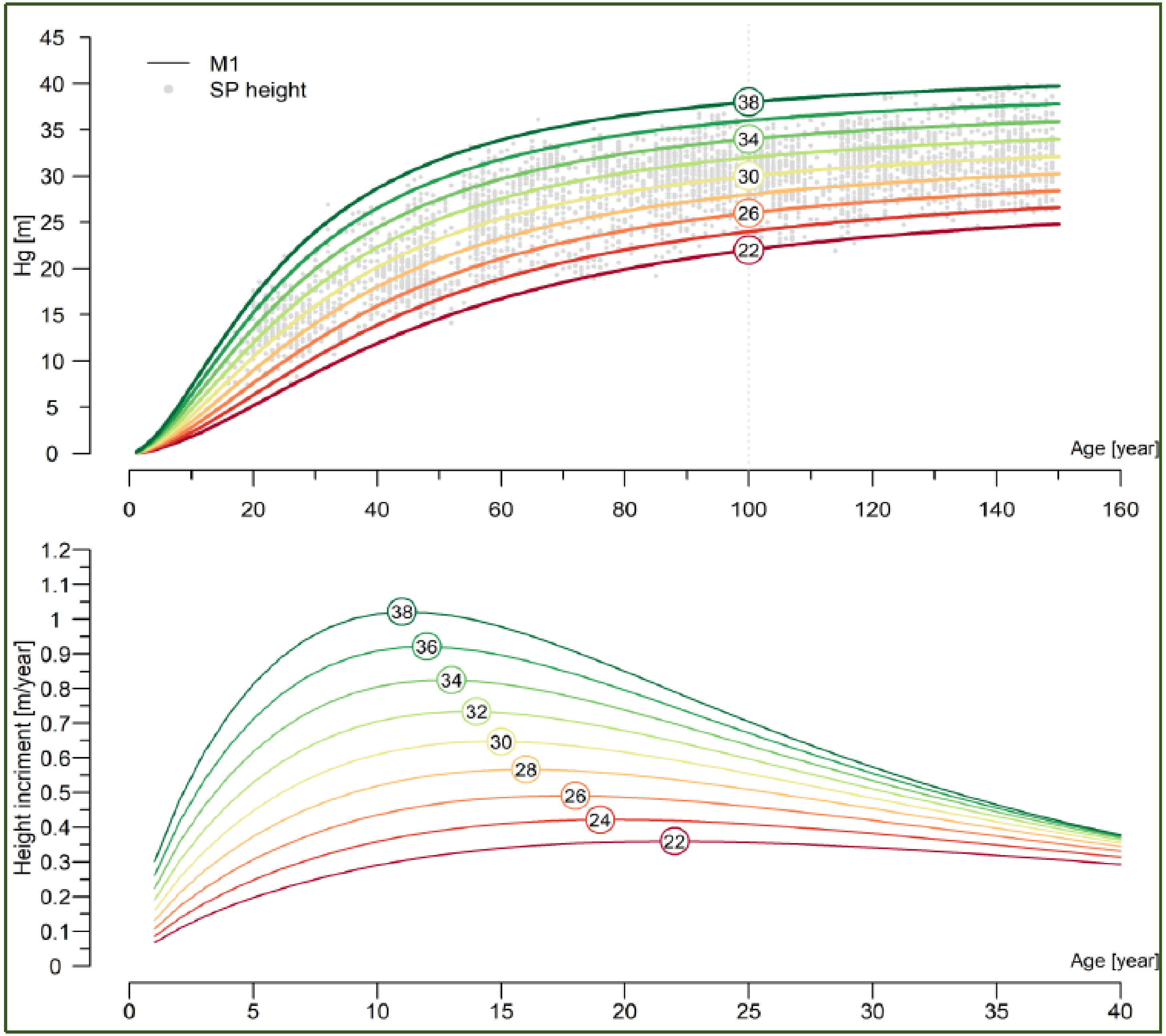
Harvesting schedule in % of standing timber volume as applied in GOTILWA+

SimYear	Stand age	BAU	Adaptation MID	Adaptation INTENSE	NoMG
2020	**20**	40	47	54	
2030	**30**	20	38	54	-
2040	**40**	18	30	43	-
2050	**50**	14	27	39	-
2060	**60**	12	24	35	-
2070	**70**	10	20	28	-
2080	**80**	9	15	21	-
2090	**90**	10	13	19	-
2100	**100**	-	-	-	-

- Stand development starting with young stands at stand age 20-30 (easily steerable)
- End at stand age 100 representing simulation year 2100
- MID Represents newly developed management guidelines
- INTENSE and NoMG represent extreme scenarios for covering wide variety for risk analyses and robust decision making

Calibration
Oak (Srem)

- **Management BAU** (without climate change)
- **13 plots** (different soil profiles from WP2)
  - Plots 6-10 mean MAI_{100} 8.7 (WP4), dominant height 28-30
    - Calibrated with **PWU 15 %**
- **One representative site type generated**



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Calibration Oak (Srem)

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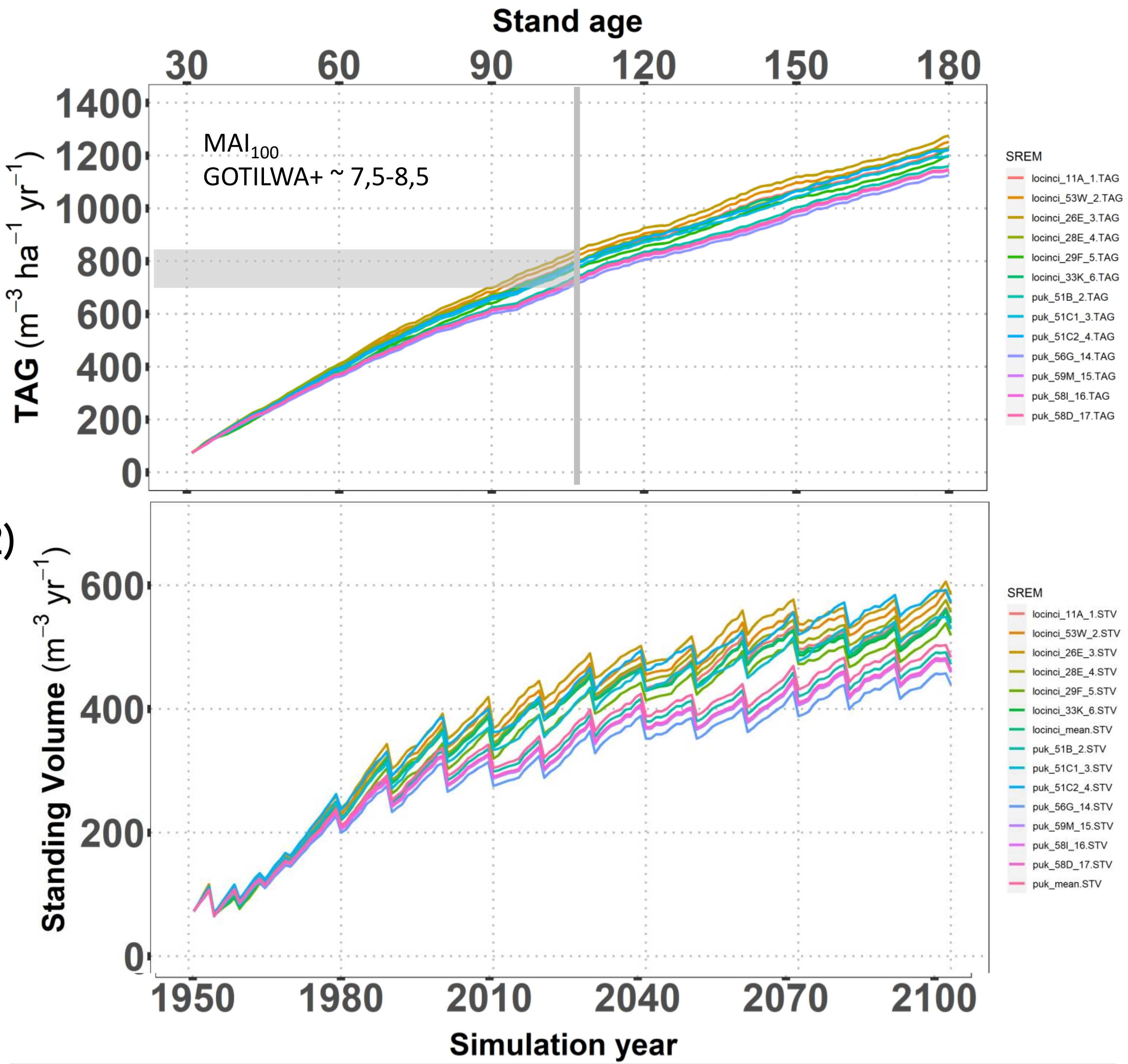
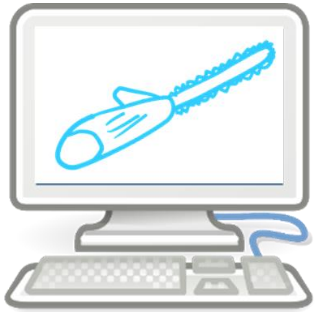
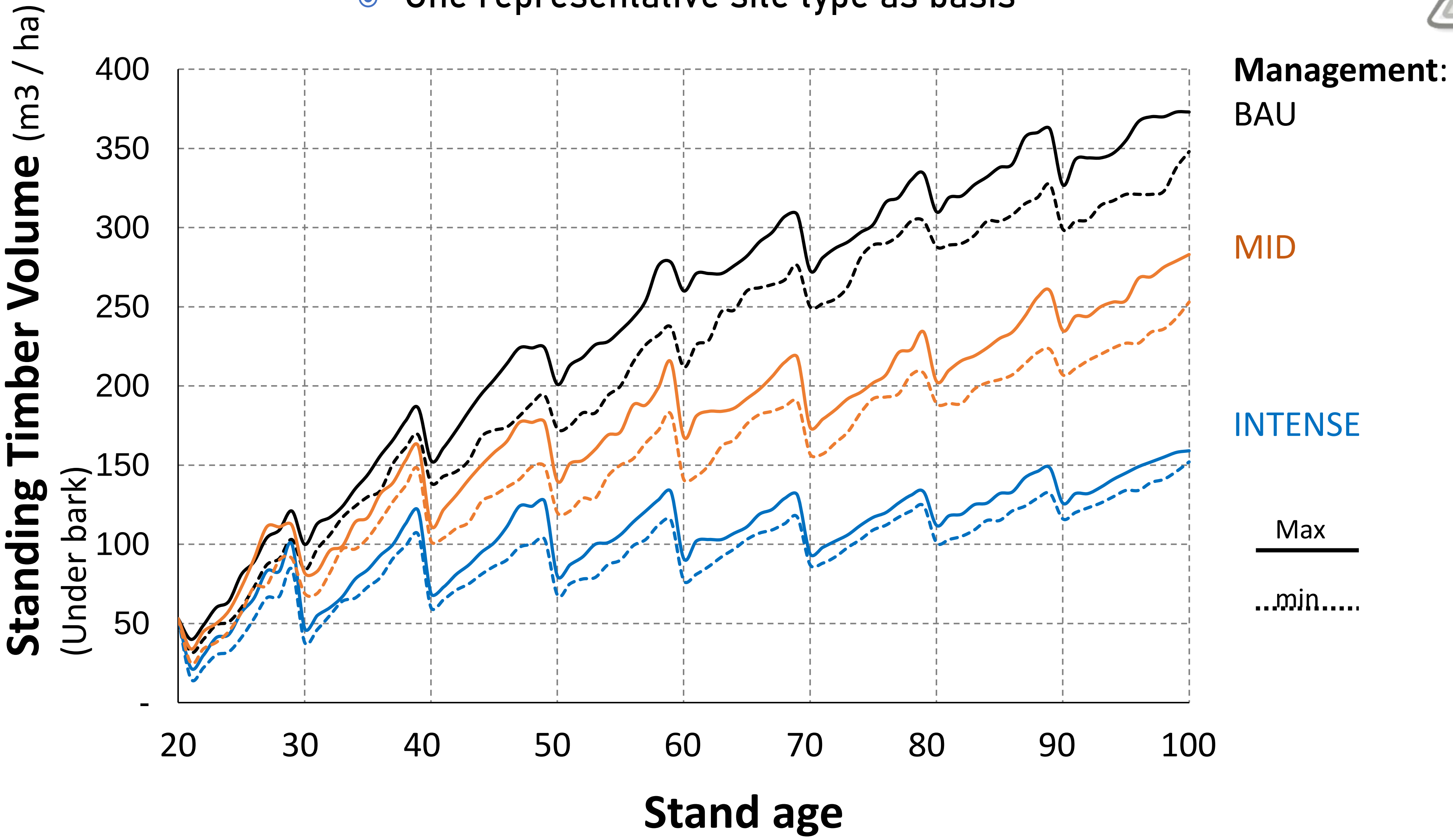
- **One representative site type generated**



Management in GOTILWA+

- Three management scenarios without climate change
- One representative site type as basis

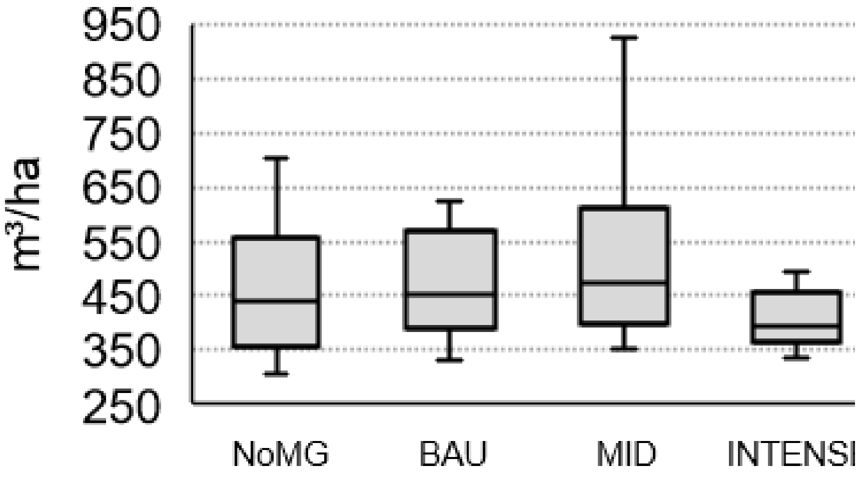




Results
Productivity

Total Accumulated Growth

In 2100 at stand age 100



NoCC

Management
No Management (NoMG)
Business-as-usual (BAU)
Moderate Adaptation (MID)
Intense Adaptation (INTENSE)

Total Accumulated Growth

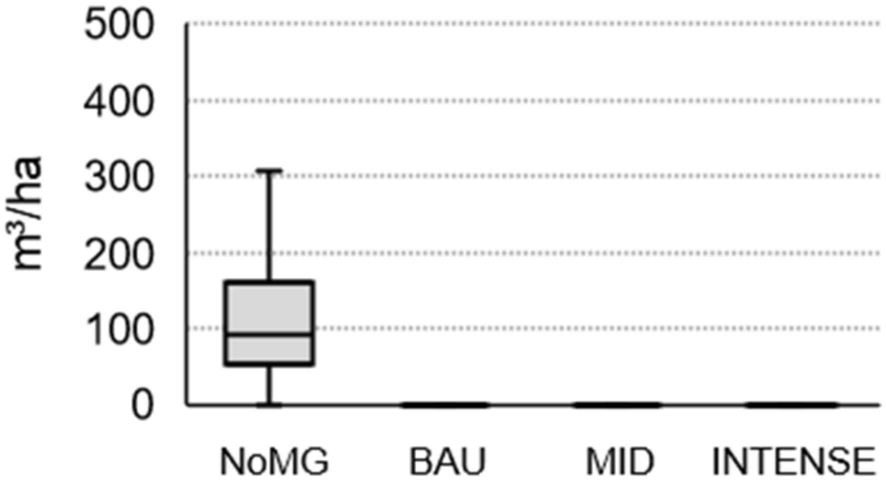
In 2100 at stand age 100

- adaptation scenario MID generated highest TAG
- BAU close to NoMG
- Very high harvesting level in INTENSE → reduces TAG
- Similar pattern under climate change but with increased productivity (vegetation lenght, CO_2, temperature)
- Productivity gains especially at the beginning of simulation period until a certain tipping point

Results
Mortality

Unplanned harvest (mortality)

accumulated in 2100 at stand age 100



NoCC

Management

No Management (NoMG)
Business-as-usual (BAU)
Moderate Adaptation (MID)
Intense Adaptation (INTENSE)

Unplanned harvest (mortality)

accumulated in 2100 at stand age 100

- Climate change increased drought induced mortality

  (other agents not build up in simulator)

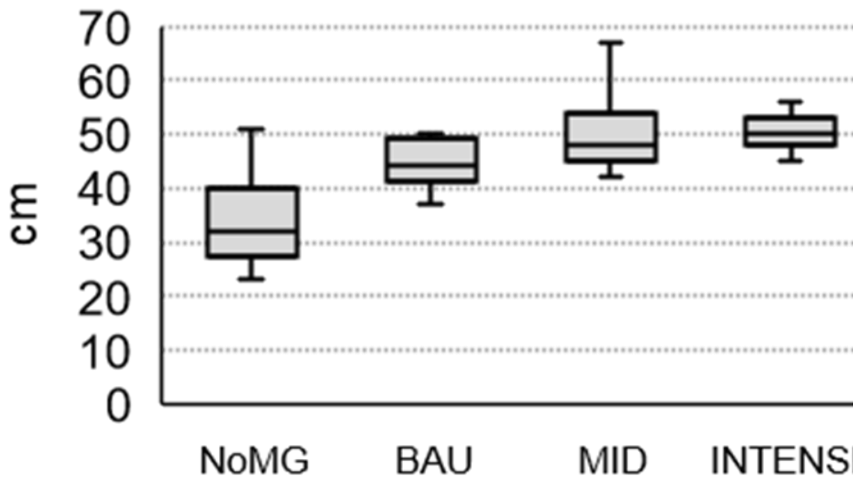
  - despite increased productivity

- **Productivity is not a good indicator for vulnerability**

Results
Future crop trees

DBH of 50 strongest trees (DBH-50)

In 2100 at stand age 100



NoCC

Management
No Management (NoMG)
Business-as-usual (BAU)
Moderate Adaptation (MID)
Intense Adaptation (INTENSE)

DBH of 50 strongest trees (DBH-50)

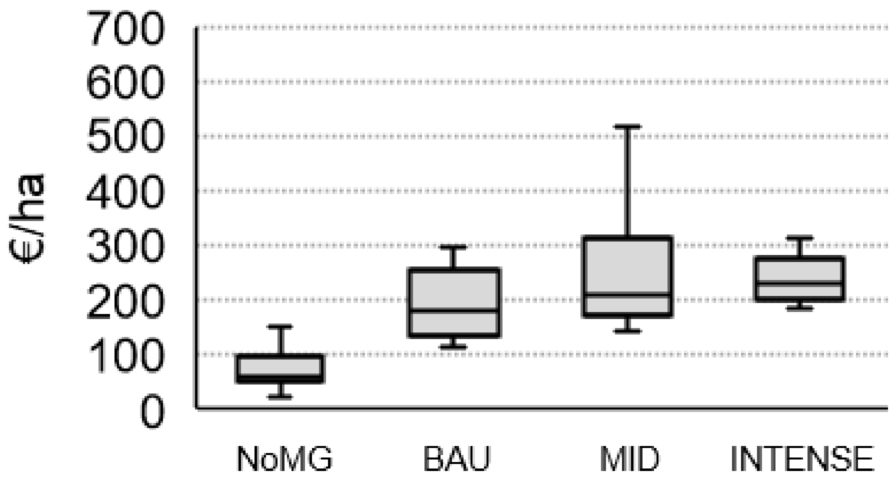
In 2100 at stand age 100

- Earlier and more intense thinnings increased notably the DBH of 50 strongest trees
- DBH-50 is good indicator for future crop trees and economic value
- Extreme scenario INTENSE generated highest DBH-50 but in MID very similar without „over-exploiting“ the forest
- Downside risk under CC increases

Results
Economic performance

Annuities (i =3 %)

2020-2100



NoCC

Management
No Management (NoMG)
Business-as-usual (BAU)
Moderate Adaptation (MID)
Intense Adaptation (INTENSE)

Annuities (i =3 %)

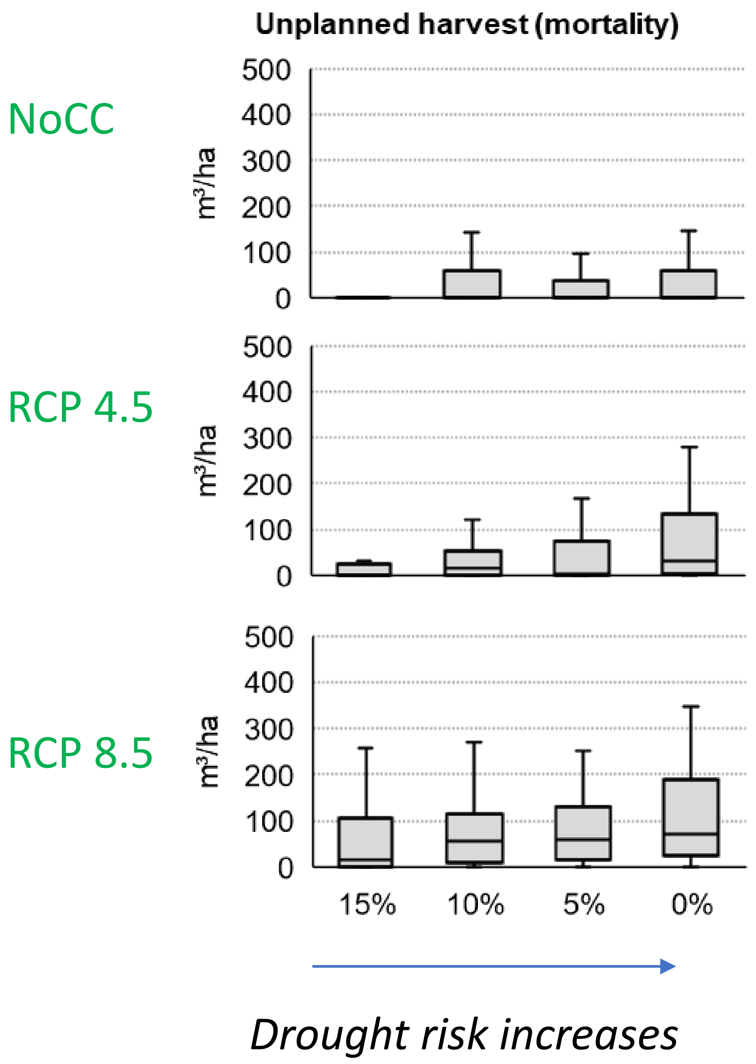
2020-2100

- Adaptation of BAU increases notably economic performance
- Annuities highest in INTENSE, but MID shows higher positive standard deviation

  → highest potential for benefits
- CC seems to increase annuities
- Strongly dependant on assumptions! Constant (historic) prices, costs and interest rates which are all highly variable
- What happens if low prices meet high mortality meets higher interest rates?
- Economic uncertainties and risks not build up!

Results
Drought risks

Declining groundwater levels



Phreatic Water Uptake (PWU)

(% of transpired water)

Declining groundwater levels

- Model calibration with PWU 15 % - lowering PWU increases mortality and strongly reduces productivity, DBH-50 and profitability
- High uncertainty regarding future – however, very high downside risks! Productivity not the main variable
- Mortality likely underestimated (only drought-induced)
- What about economic risk factors?

Economic model including uncertainties of ….

Roundwood prices

- 51

Harvesting costs

- 11

Capital costs

- 3 levels DDR
- 3 levels CDR

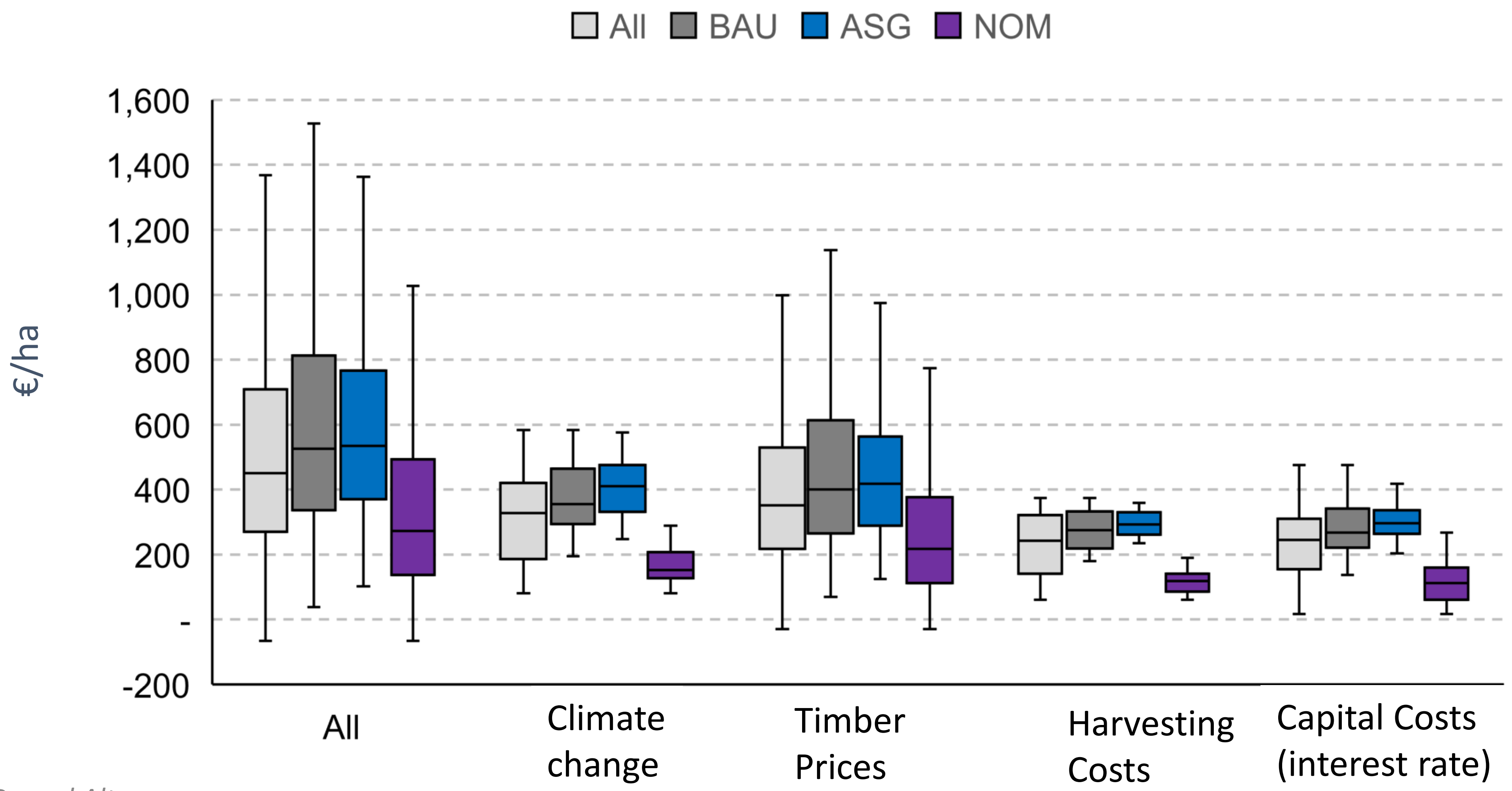
= 3366 combinations

X

432 GOTILWA+ simulations

= 1,454,122 combinations of what could happen in the future

Variability of the annuity with uncertainties



Slide curtesy Danyal Altunay

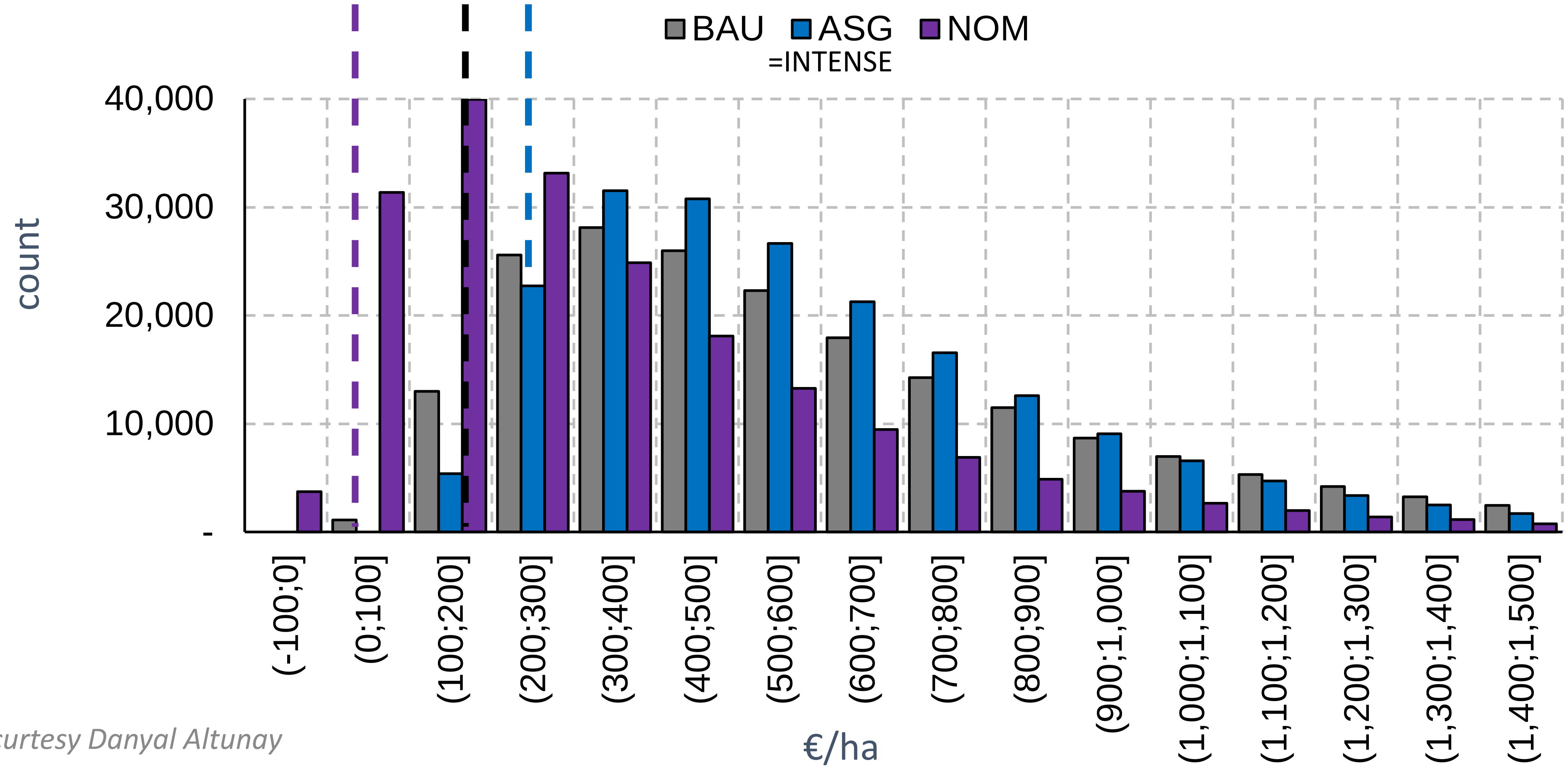
Distribution of the annuity (€/ha)

Value at risk (VaR)

5 % chance that annuities are **lower** than threshold

VaR⁹⁵

95 % chance that annuities are **higher** than threshold



Slide curtesy Danyal Altunay

Robust metric of risk analyses

- Upside risk is not a risk but a chance → no need to prepare for that

- **Downside risk is critical**: measure for projected losses when return is lower than indicated threshold
→ includes our worst nightmares! Get ready for that

- Distribution of annuities of all combinations (states of the world) show an improvement through the adaptation

- INTENSE enhances robustness by ca 30-60% despite reduced productivity (on average ca. 15%)

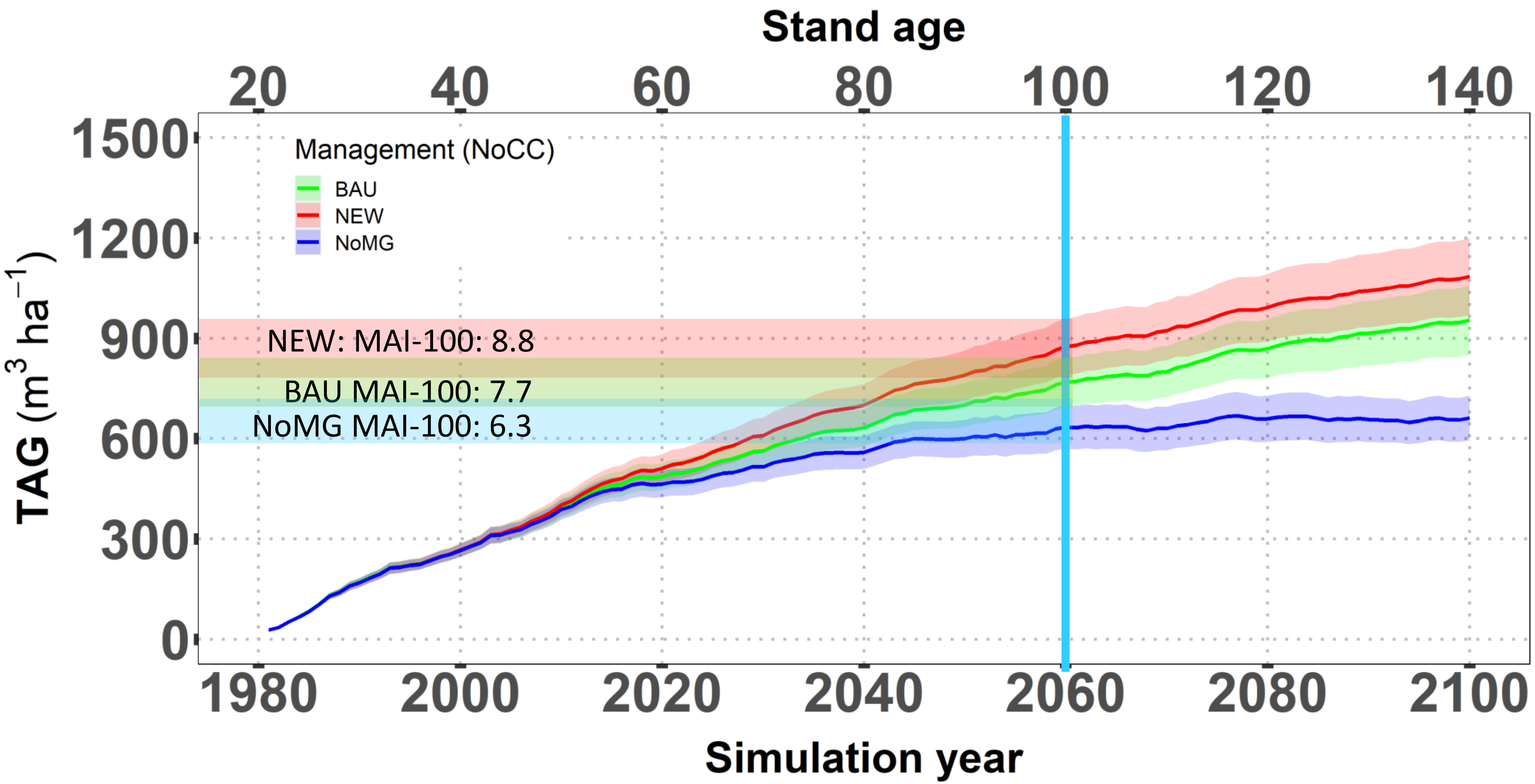
Results
Productivity
With climate change
Tara - limestone

Results Productivity
(no climate change)
Tara

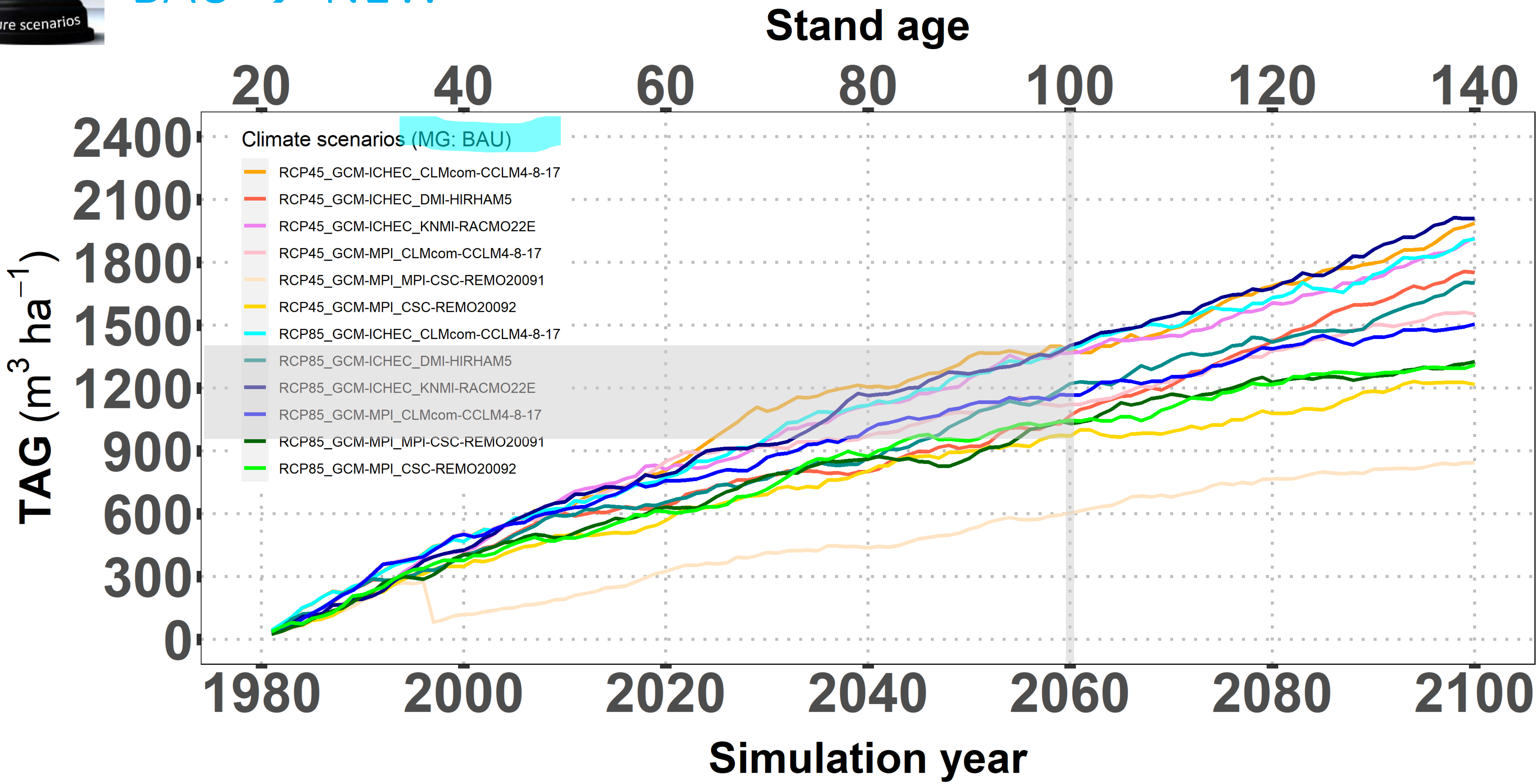
N= 13 simulations
13 plots available for TARA with soil profile data and productivity data (Marko)
Fig. shows mean with ribbons (confidence interval)

Harvesting volume (m3/ha) in GOTILWA+
Absolute values

Age classes	BAU	Intense (new)
0-10	0	0
10-20	0	0
20-30	0	15
30-40	40	**103**
40-50	**76**	**128**
50-60	**78**	**111**
60-70	**73**	**112**
70-80	**72**	**86**
80-90	**70**	**72**
90-100	**57**	**68**
100-110	**207**	148
>120	**163**	150



Simulation Results: Total accumulated growth BAU → NEW



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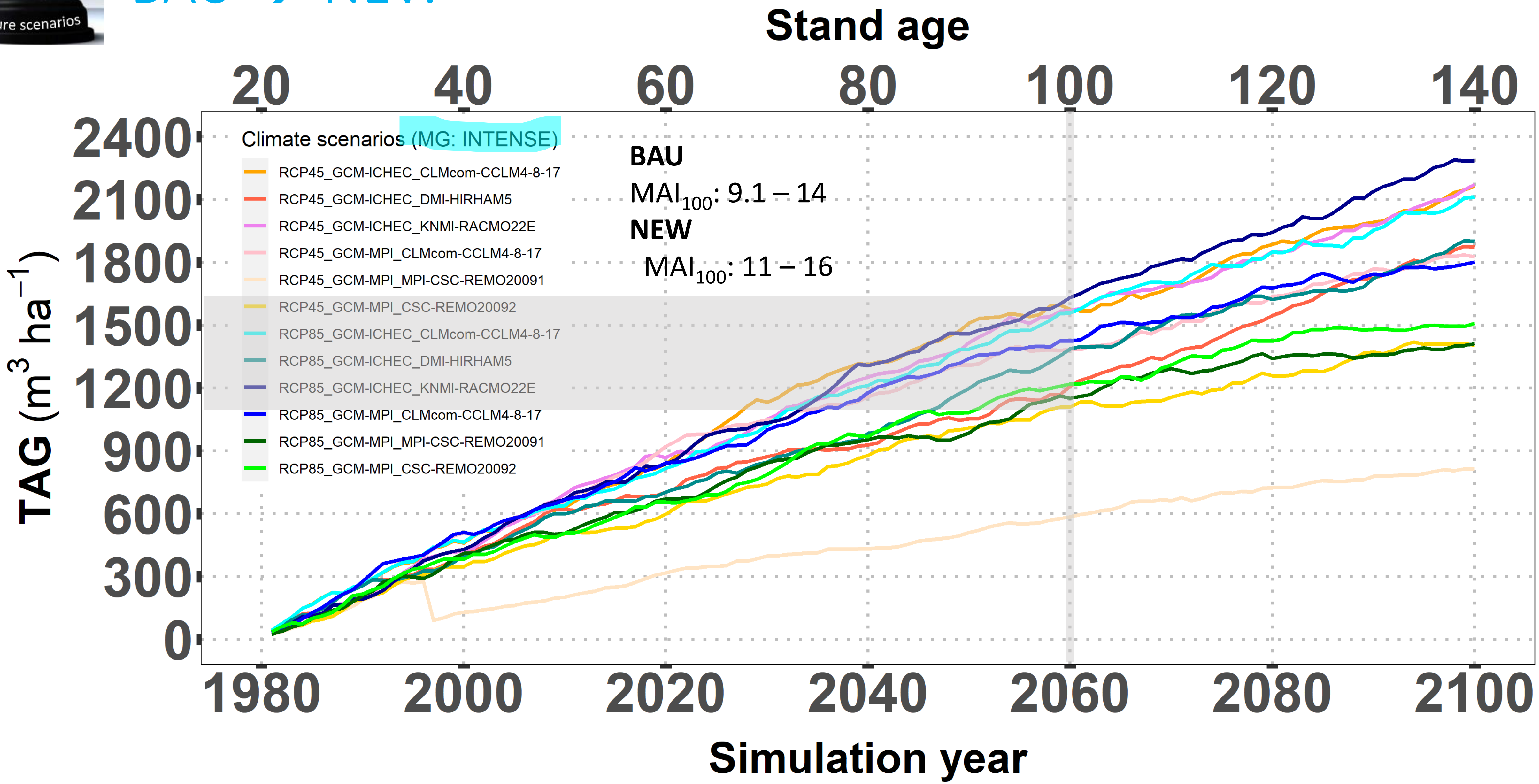
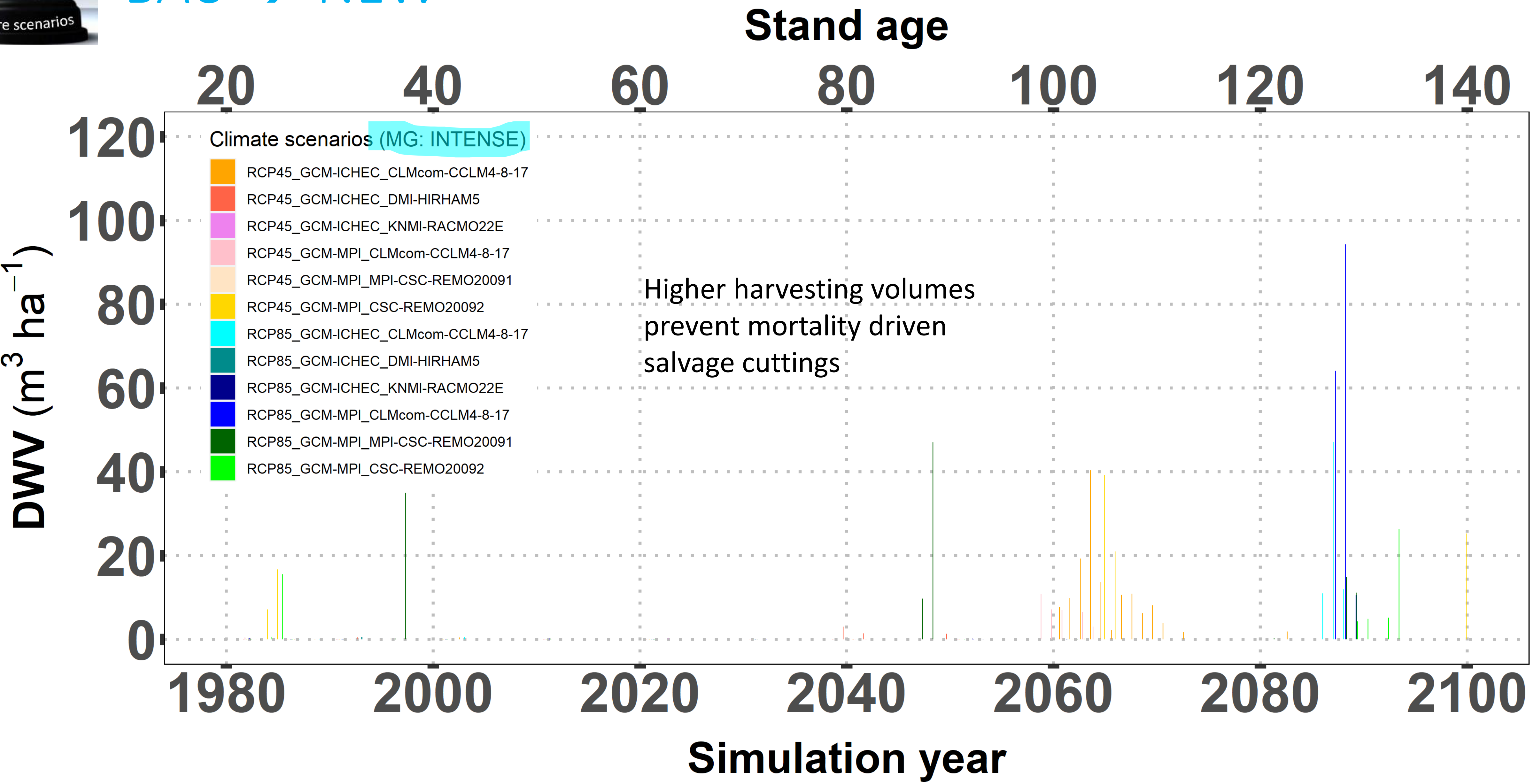
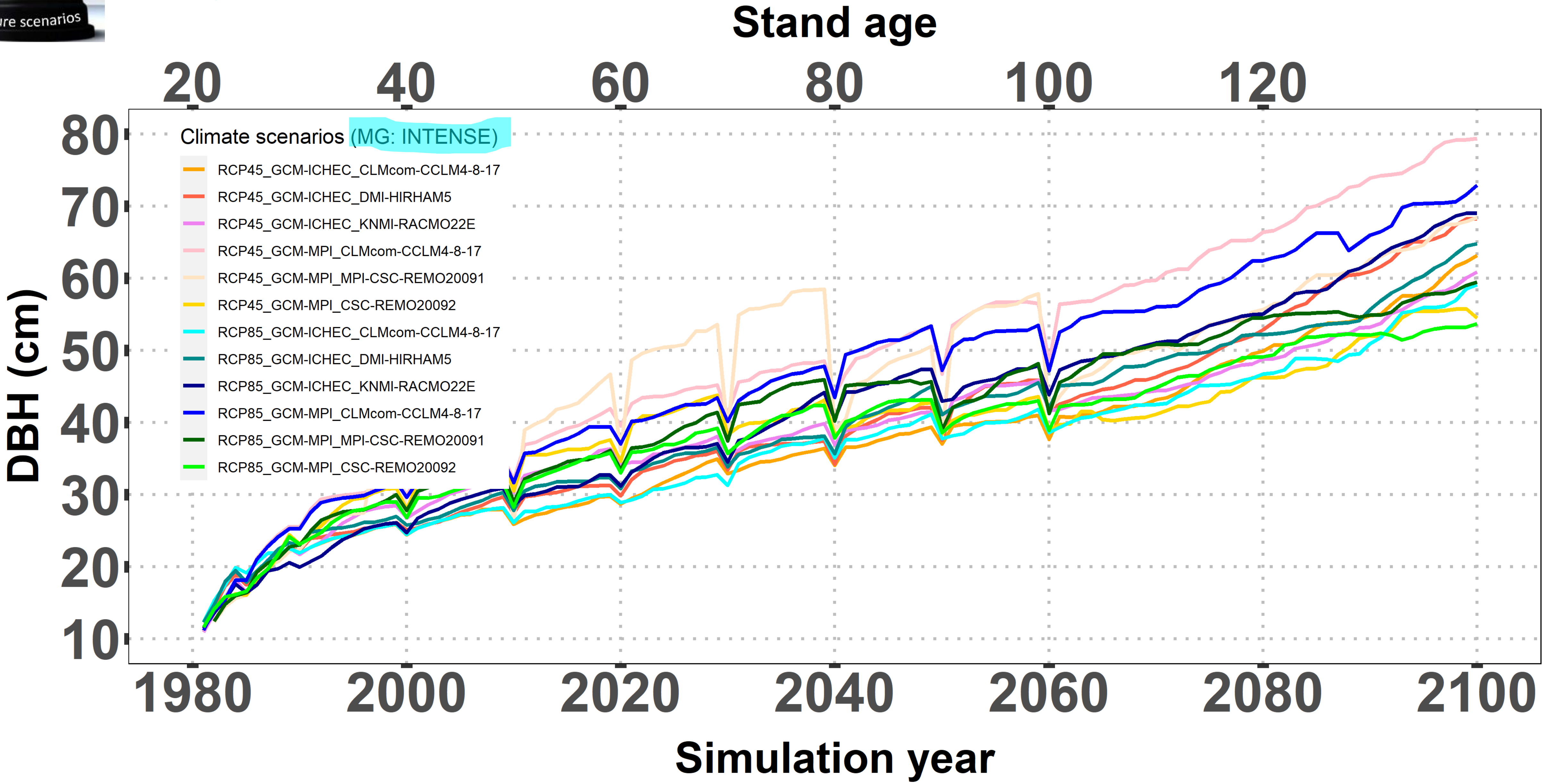


Simulation Results: Dead Wood Volume
BAU → NEW



Simulation Results: DBH
BAU → NEW



Study area Tara

Conclusion Climate change simulations

- Mortality risks increased notably, especially on shallow soils (not shown)

→ Highly variable between scenarios (CC uncertainty), but mostly negative consequences.

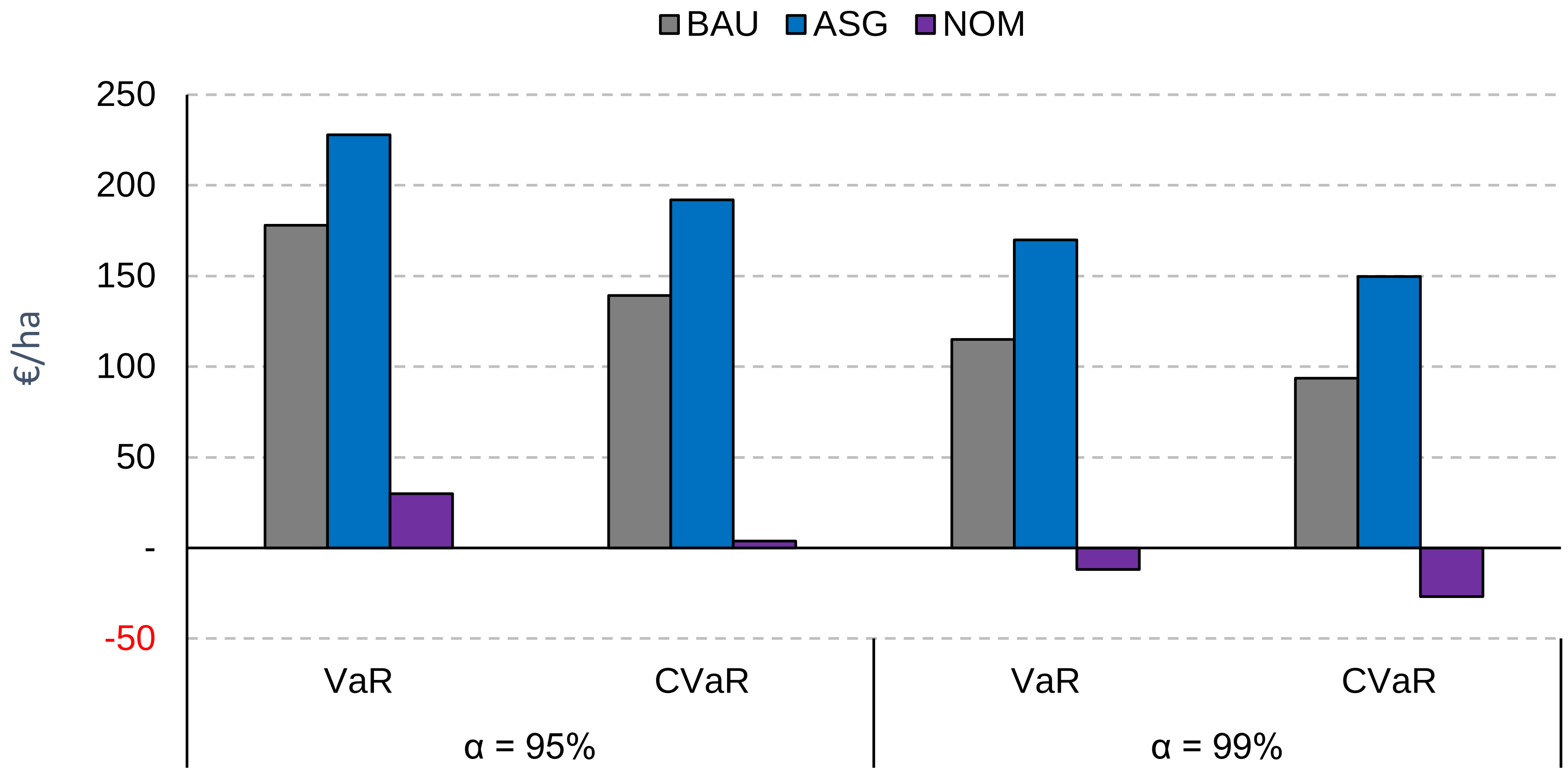
- Mean DBH notably higher in NEW

→ Target diameter can be reached in shorter time

Comedy Wildlife Photo Awards Finalists

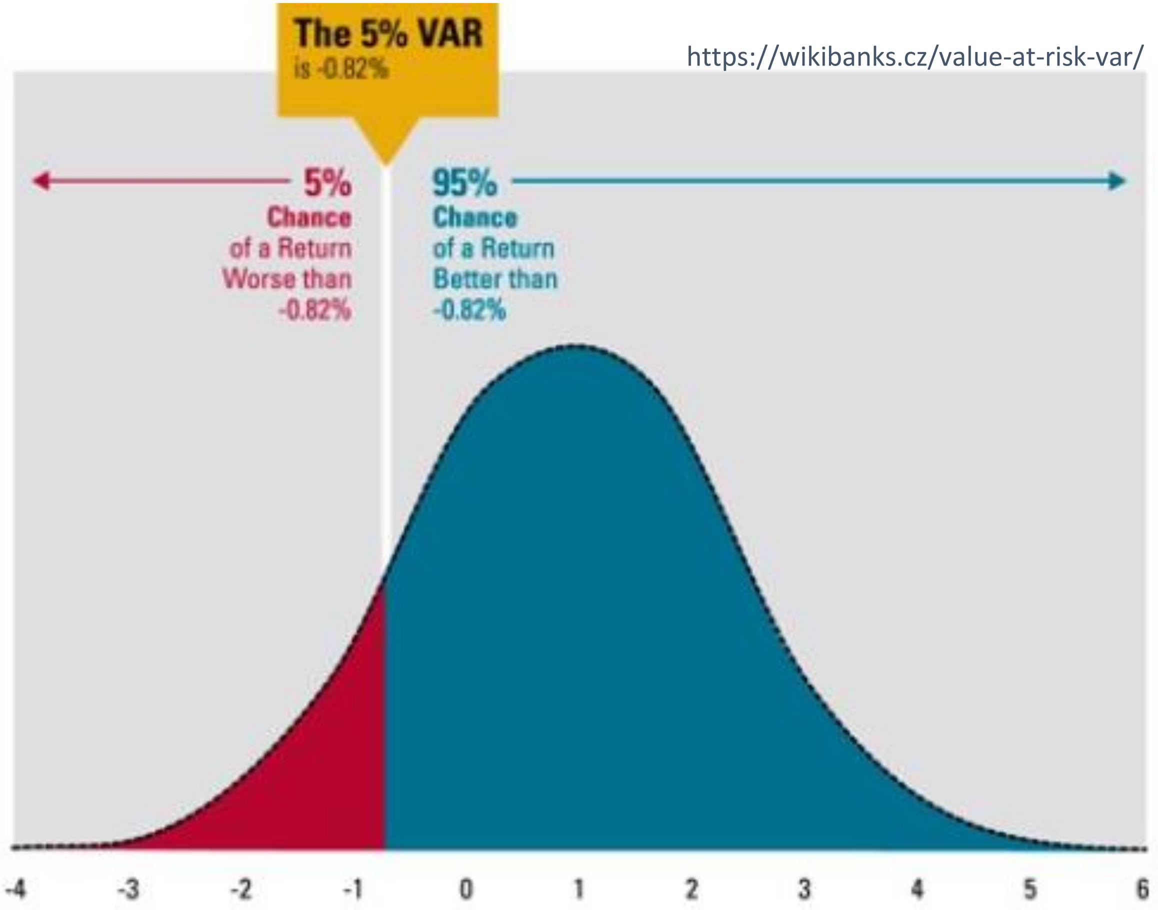
VaR and CVaR depending on confidence level

Substantially higher robustness of the ASG



Robustness metrics

Value at Risk (VaR) and Conditonal Value at Risk (CVaR)



https://wikibanks.cz/value-at-risk-var/

Simulation Setup: Management

- Problem under CC: major mortality events or productivity losses make absolute and static harvesting values unrealistic in the simulator → need for a dynamic management approach under climate change for GOTILWA+
- Absolute harvesting volumes from BAU and NEW under current climate (no climate change) (1) are translated into relative values of standing volume (% of increment not possible in GOTIWLA+) (2) and applied in climate scenarios

1

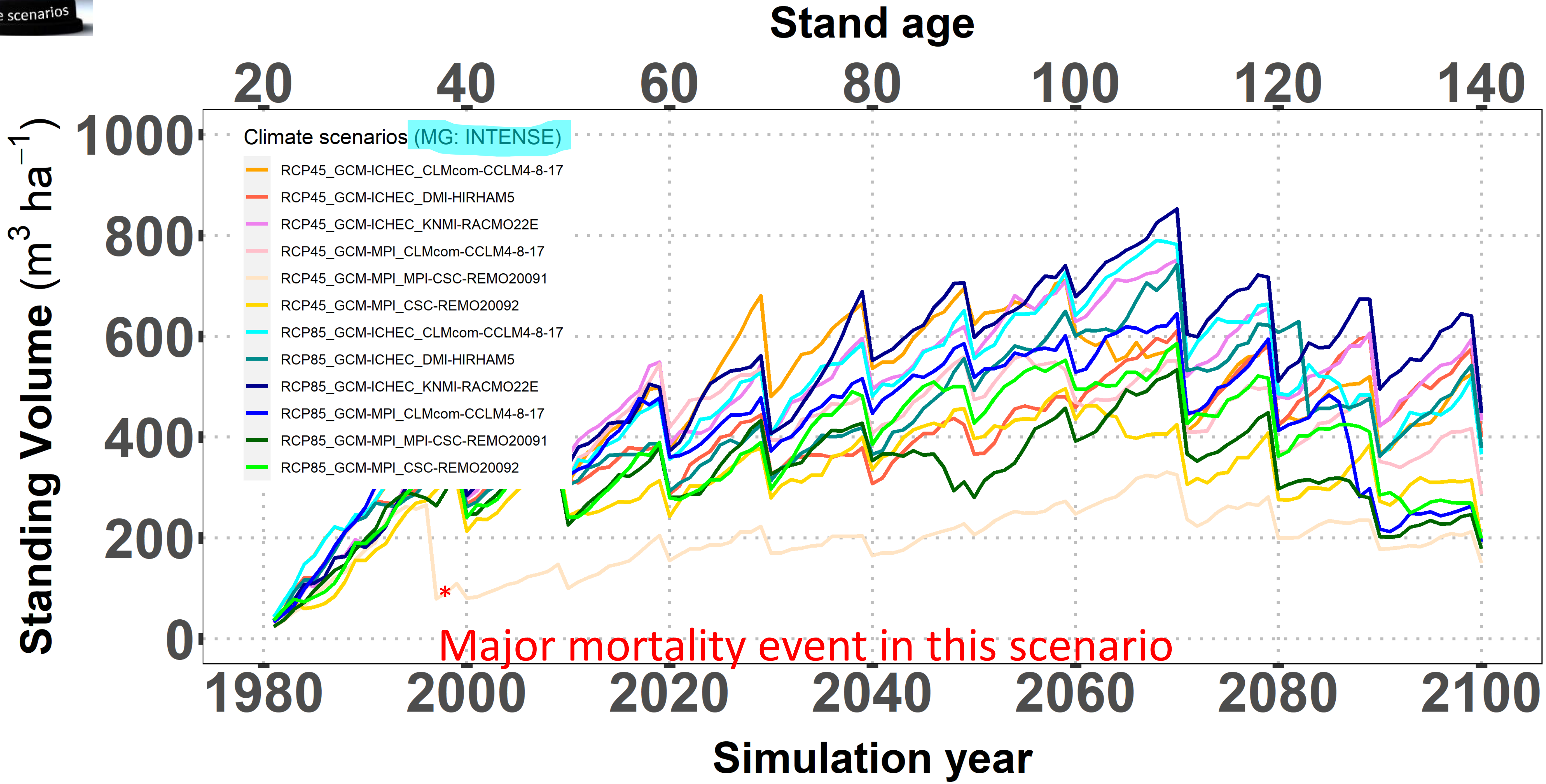
Absolute Harvesting (m3 /10 yrs./ ha)		
Age class	**BAU**	**NEW**
20-30	0	14
30-40	40	103
40-50	76	126
50-60	76	112
60-70	71	88
70-80	71	88
80-90	68	71
90-100	59	63
100-110	268	139
120-130	268	139
130-140	268	139

2

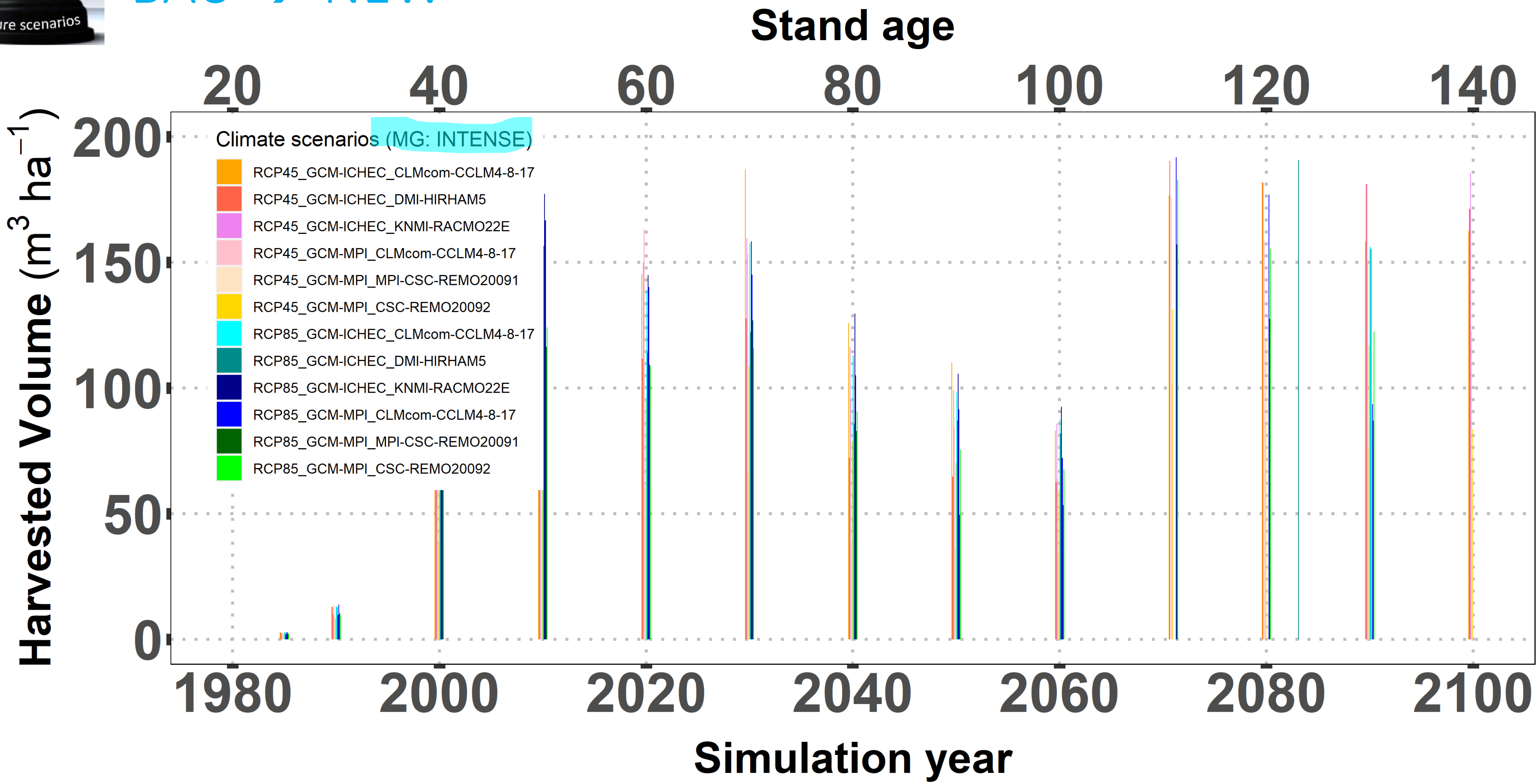
Relative Harvesting (% of Standing Volume)		
Age class	**BAU**	**NEW**
20-30	**0**	5
30-40	10	32
40-50	15	34
50-60	15	28
60-70	13	28
70-80	12	19
80-90	12	15
90-100	9	12
100-110	43	43
120-130	43	43
130-140	43	43

Age classes	BAU absolute	BAU Relative	NEW absolute	NEW relative
0-10	0	0	0	0
10-20	0	0	0	0
20-30	0	0	15	5
30-40	40	10	103	32
40-50	76	15	128	34
50-60	78	15	111	28
60-70	73	13	112	28
70-80	72	12	86	19
80-90	70	12	72	15
90-100	57	9	68	12
100-110	207	43	148	43
>120	163	43	150	43

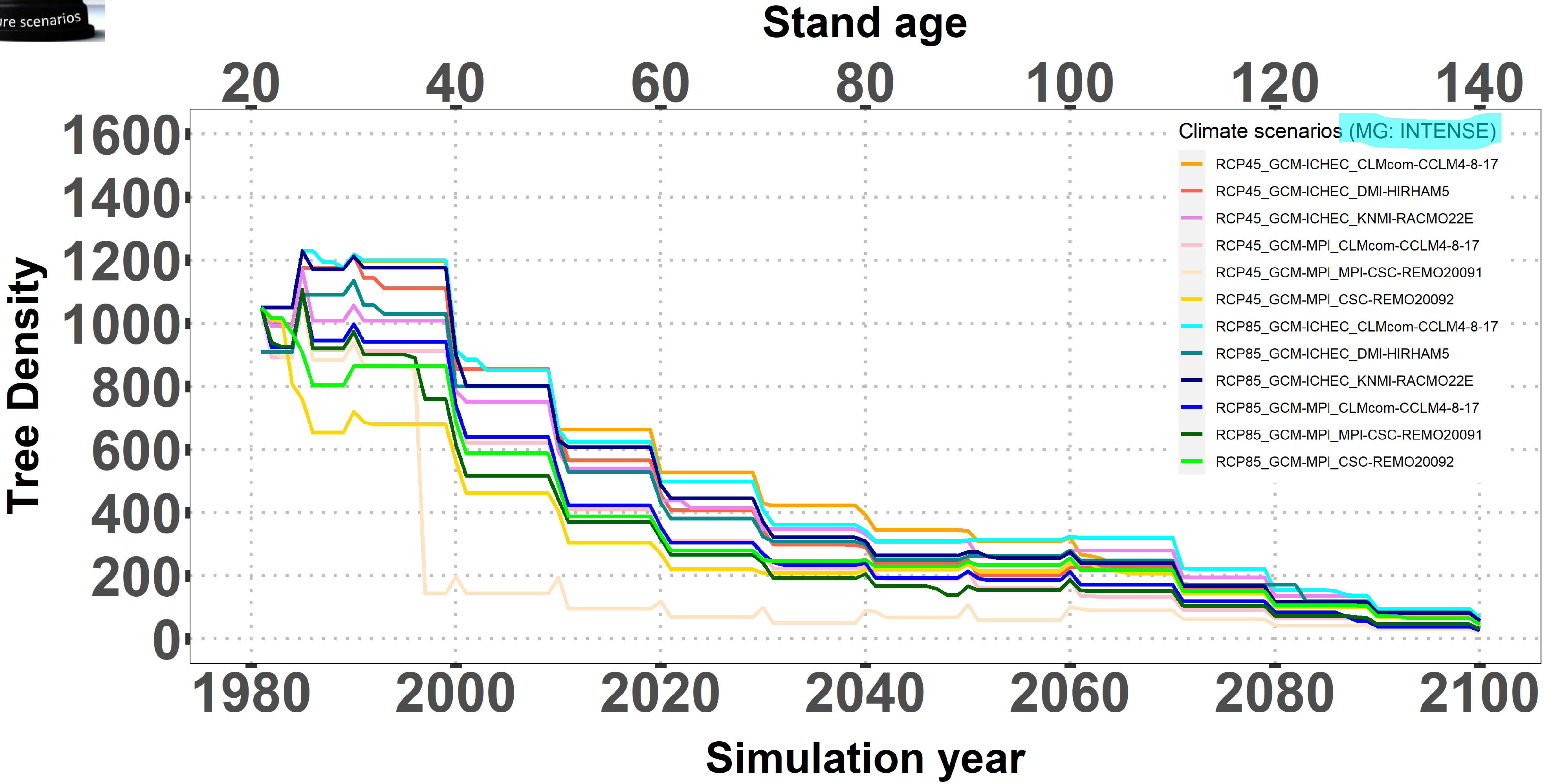
Simulation Results: Standing Volume
BAU → NEW



Simulation Results: Harvested volume
BAU → NEW



Simulation Results: Tree density BAU → NEW



Simulation Results: Leaf Area Index

BAU → NEW