

Optimizing the management of even-aged beech stands under climate change uncertainty

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Climate change, uncertainty and decision making

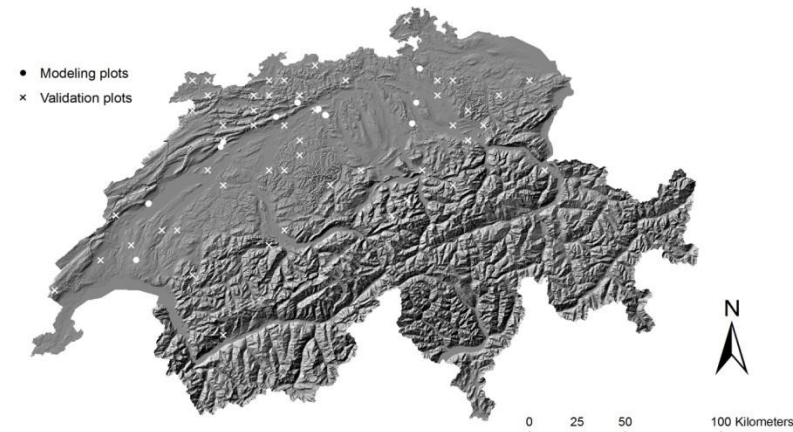
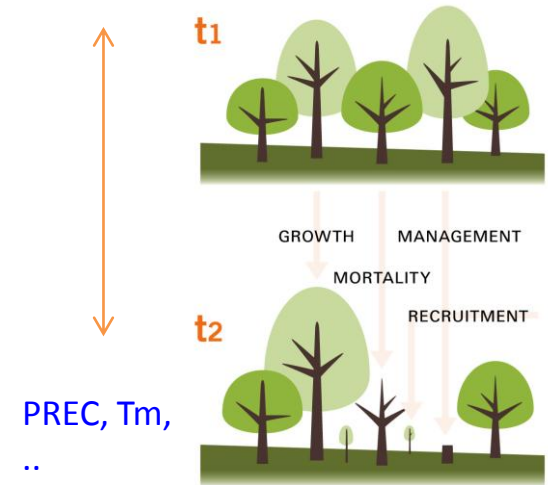
- For decision making under uncertainty we need to explore the performance of many alternative management strategies under various climate scenarios
- We need to select optimized management scenarios contingent (dependent on something not yet certain) on potential climate change
- Climate sensitive simulators of forest ecosystems are essential for this
- Most climate sensitive simulators are process based ecological models, too heavy for advanced decision exploration and optimization
- Climate sensitive growth and yield model for EA beech stands in Switzerland developed for this purpose

Questions addressed

- What is the implied risk – the potential loss - of being 'wrong' about what climate development is being realized?
- Using a case of Beech in Switzerland, we conclude on:
 - a) to what degree climate change affects optimal decisions
 - b) under what site conditions is "being wrong" potentially problematic vs. conditions in which we may be less concerned
- Develop a model/approach that can be directly used to support practical adaptive forest management

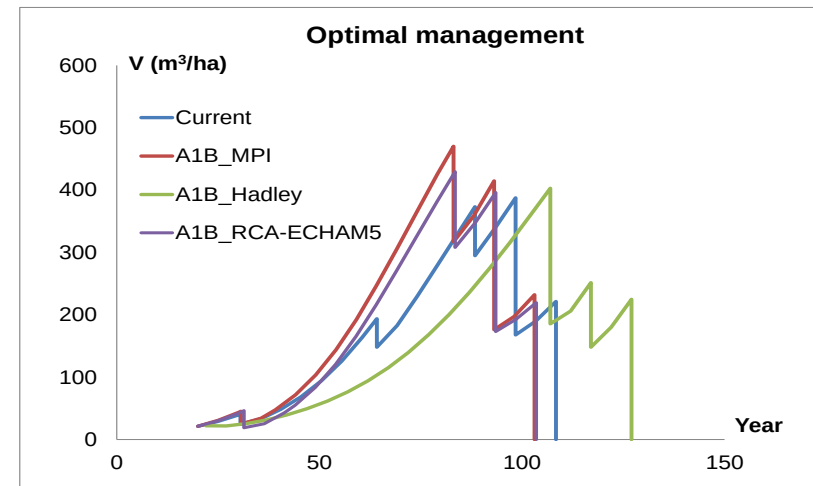
The growth and yield model

- Individual-tree empirical model, project tree growth and mortality (size, competition, [site](#))
- [Site](#) effects integrated using explicit climatic, soil and topog. factors
 - DI (drought index combining PREC, PET and soil WHC)
 - GDD_1 (Sum degree-days index)
- Represent the range/amplitude in “climate x local site” conditions for the species
 - WSL data: long-term trials (70 y); Swiss NFI; Daymet_CH interpolated climate data; soil data on WHC



The planning model

- Shelterwood even-aged management;
Typical initial state (diam. dist.) at 20y used
- For a given climate scenario and nr./type of thinnings: Determine timing and intensity with decision variables: Age_TH1; Int_TH1; Age_TH2; Int_TH2; Age_RC1
- So that a given objective function is maximized:
 - LEV (Economic efficiency; a given set of Assortments, Prices, Costs is selected)
 - Biomass production (mean annual m^3/ha ,...)
 - Other..



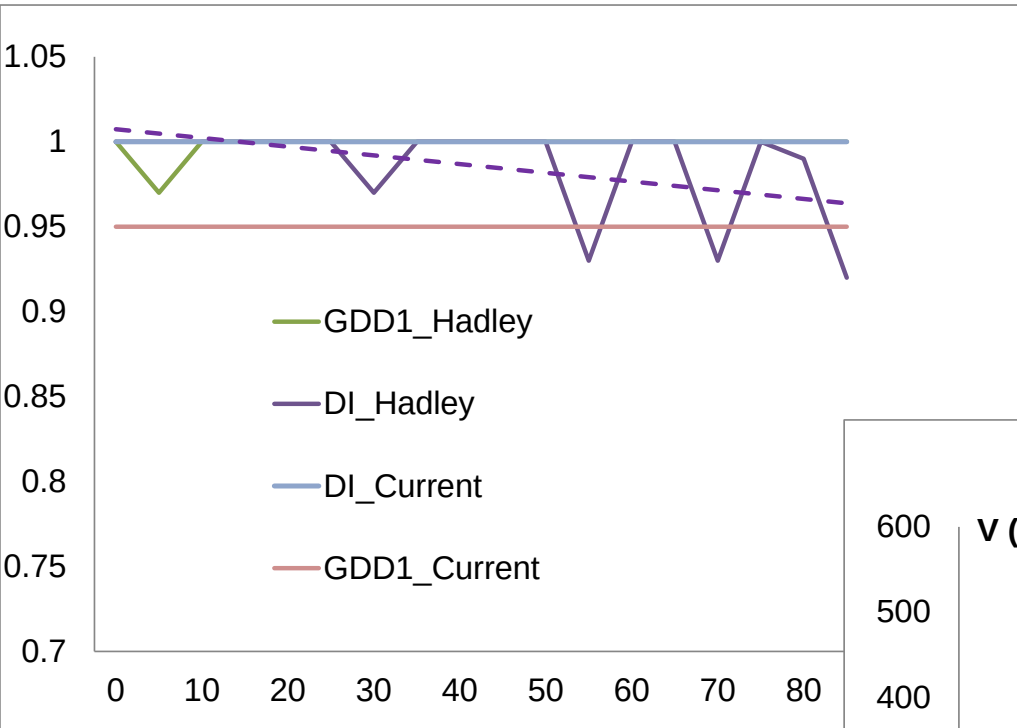
PRELIMINARY RESULTS FOR SOME REPRESENTATIVE STANDS ALONG THE “CLIMATE x LOCAL SITE” RANGE FOR THE SPECIES

4 CLIMATE SCENARIOS:

Current, A1B_MPI, A1B_Hadley, A1B_RCA-ECHAM5

SAME THINNING REGIME/TYPE (2 INTERMEDIATE THINNINGS),
OBJECTIVE FUNCTION (LEV2%), TYPICAL ASSORTMENTS AND
STUMPAGE PRICES

HIGH PRODUCTIVITY: DI_Current = 1 (WHC = 214 mm) ; GDD1_Current = 0.95;

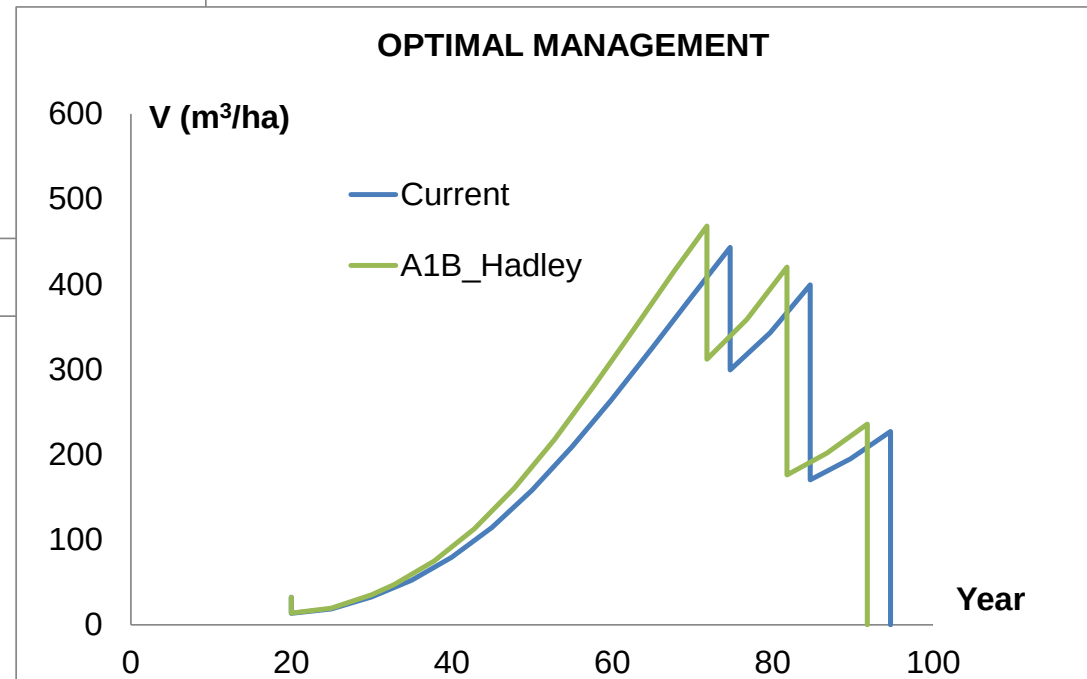


DI and GDD1 Range:] 0 , 1]

If DI = 1 → No drought

If GDD1 = 1 → No temp. Sum limitation

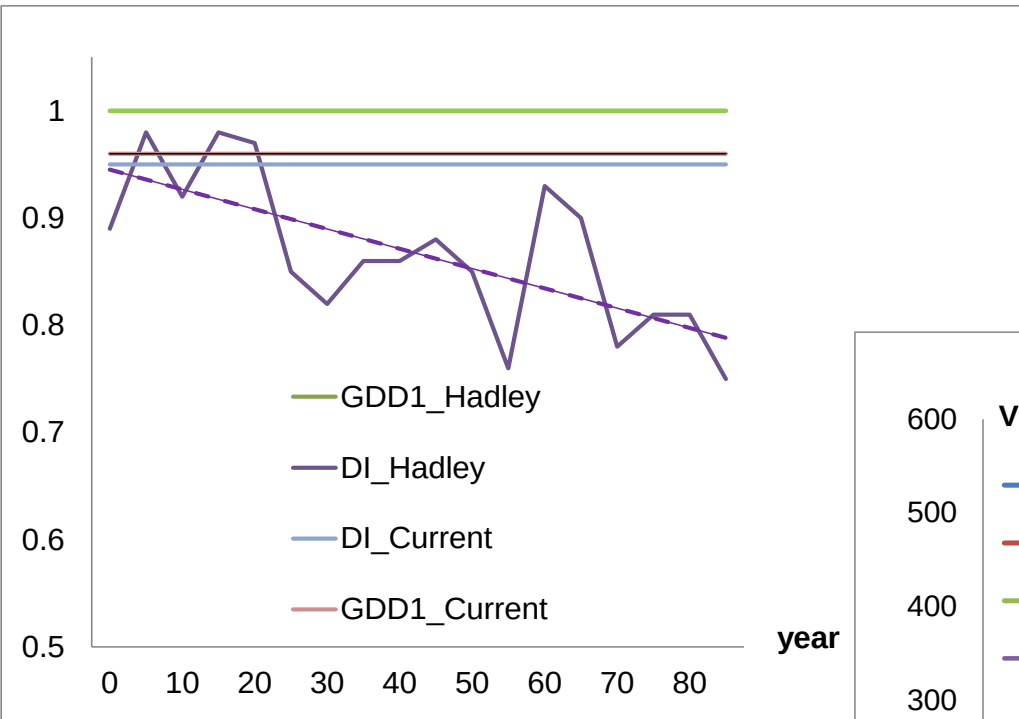
Small change..



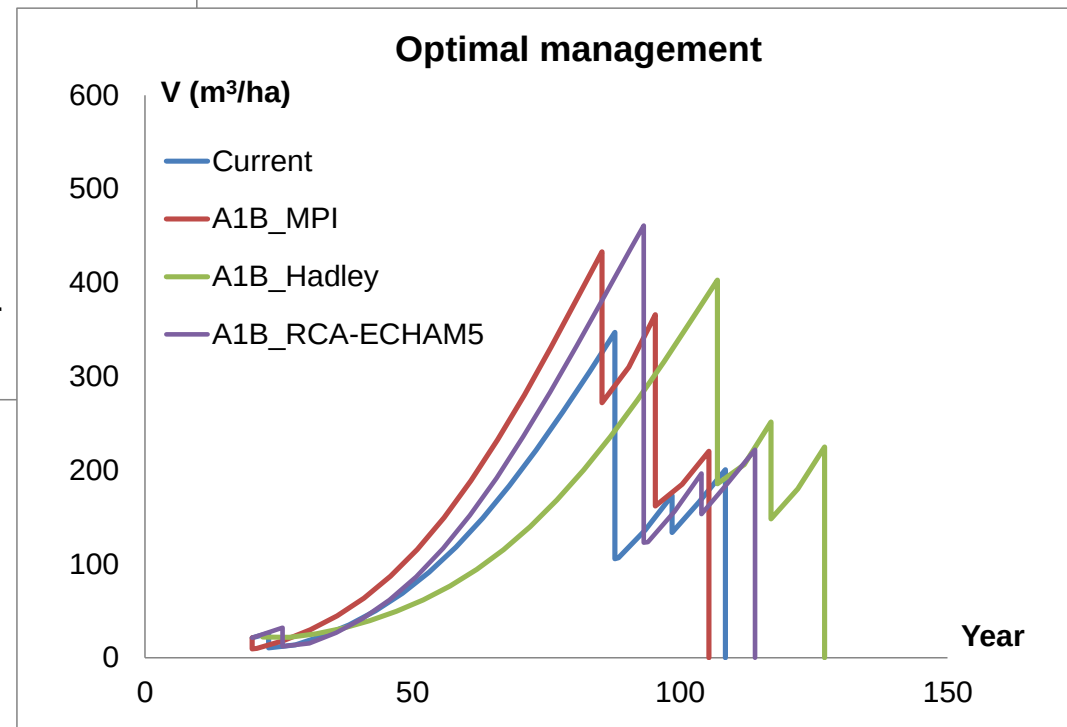


LEV2 (CHF/ha) WP (m ³ /ha*y)	MANAGEMENT OPTIMIZED FOR:				
REALIZED CLIMATE	CURRENT	A1B_MPI	A1B_HADLEY	A1B_RCA-ECHAM5	LOSS%
CURRENT	LEV2 = 4967.2; WP=6.3	LEV2 = 4967.2; WP=6.3	LEV2 = 4885.4; WP=6.5	LEV2 = 4885.4; WP=6.5	1.7
A1B_MPI	LEV2 = 5013.2; WP=6.3	LEV2 = 5013.2; WP=6.3	LEV2 = 4885.4; WP=6.5	LEV2 = 4885.4; WP=6.5	2.6 (128)
A1B_HADLEY	LEV2 = 5840.6; WP=7.1	LEV2 = 5840.6; WP=7.1	LEV2 = 5860.1; WP=7.1	LEV2 = 5860.1; WP=7.1	0.4
A1B_RCA-ECHAM5	LEV2 = 5840.6; WP=7.1	LEV2 = 5840.6; WP=7.1	LEV2 = 5860.1; WP=7.1	LEV2 = 5860.1; WP=7.1	0.4

MEAN-HIGH PRODUCTIVITY: DI_Current = 0.95 (WHC = 189 mm); GDD1_Current = 0.96

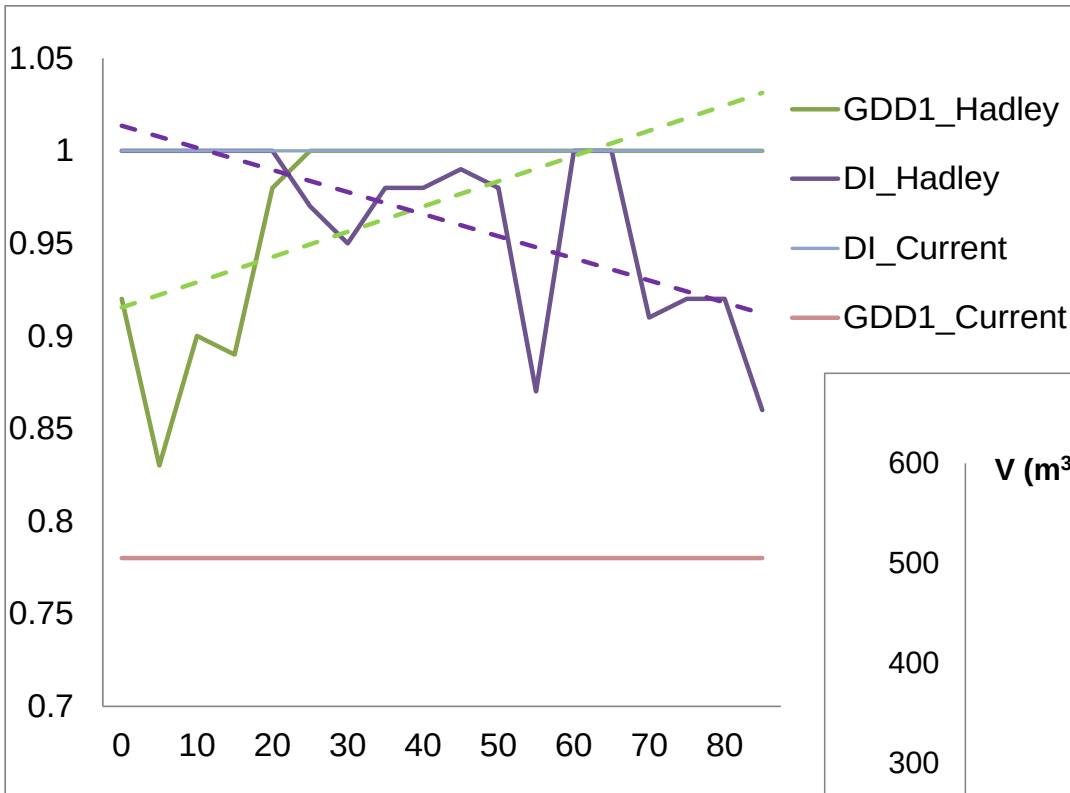


NPP decrease

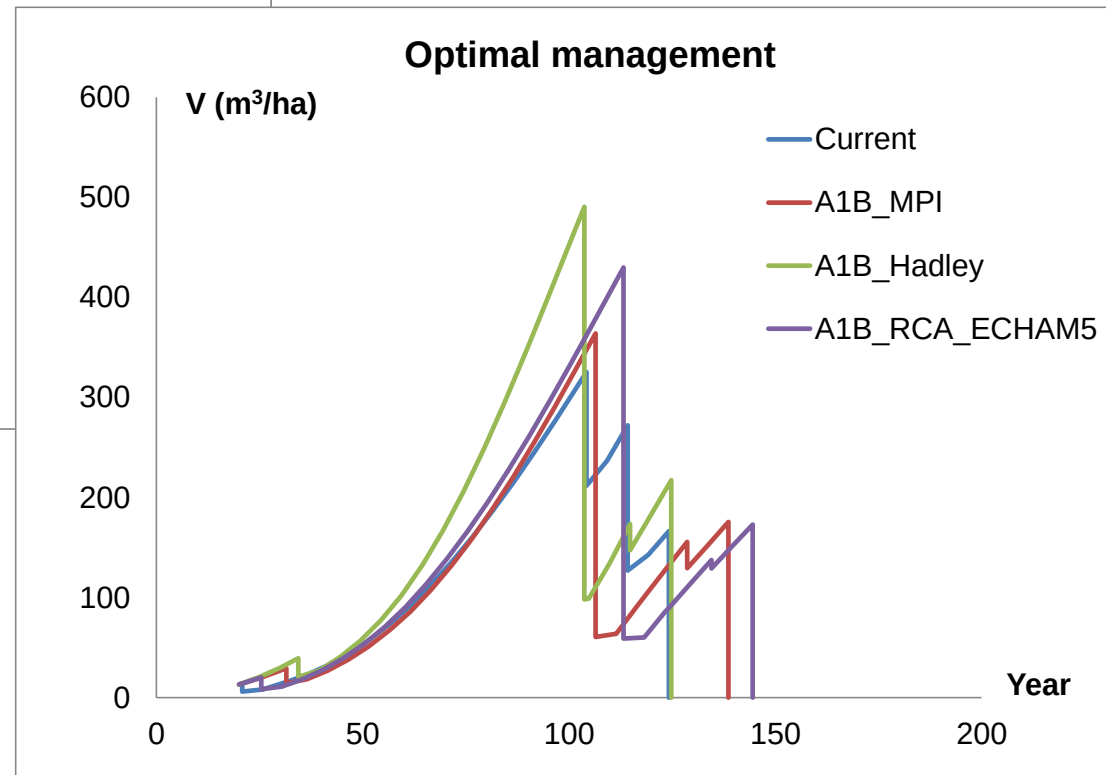


LEV2 (CHF/ha) WP (m ³ /ha*y)	MANAGEMENT OPTIMIZED FOR:				
REALIZED CLIMATE	CURRENT	A1B_MPI	A1B_HADLEY	A1B_RCA- ECHAM5	LOSS%
CURRENT	LEV2 = 3185.3; WP=4.6	LEV2 = 3104.1; WP=4.7	LEV2 = 3101.8; WP=4.4	LEV2 = 3163.6; WP=4.7	2.6
A1B_MPI	LEV2 = 4191.2; WP=5.6	LEV2 = 4304.4; WP=5.7	LEV2 =3806.2; WP=5.3	LEV2 = 4091; WP=5.7	11.6 (498.2)
A1B_HADLEY	LEV2 = 2222; WP=3.8	LEV2 =2300.6; WP=3.9	LEV2 = 2303; WP=3.8	LEV2 = 2217.6; WP=3.9	3.7
A1B_RCA- ECHAM5	LEV2 = 3922.4; WP=5.3	LEV2 =3932.2; WP=5.4	LEV2 = 3616.7; WP=5.1	LEV2 = 3955.1; WP=5.5	8.6

MEAN-LOW PRODUCTIVITY: DI_Current = 1 (WHC = 210 mm) ; GDD1_Current = **0.78**;

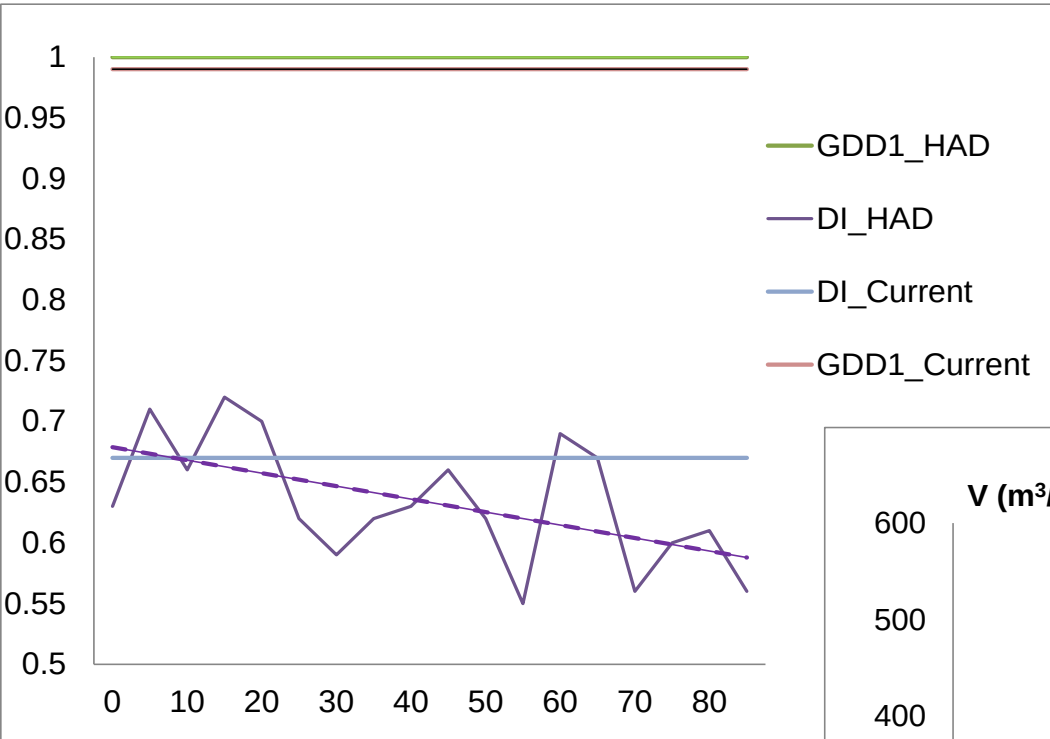


NPP increase

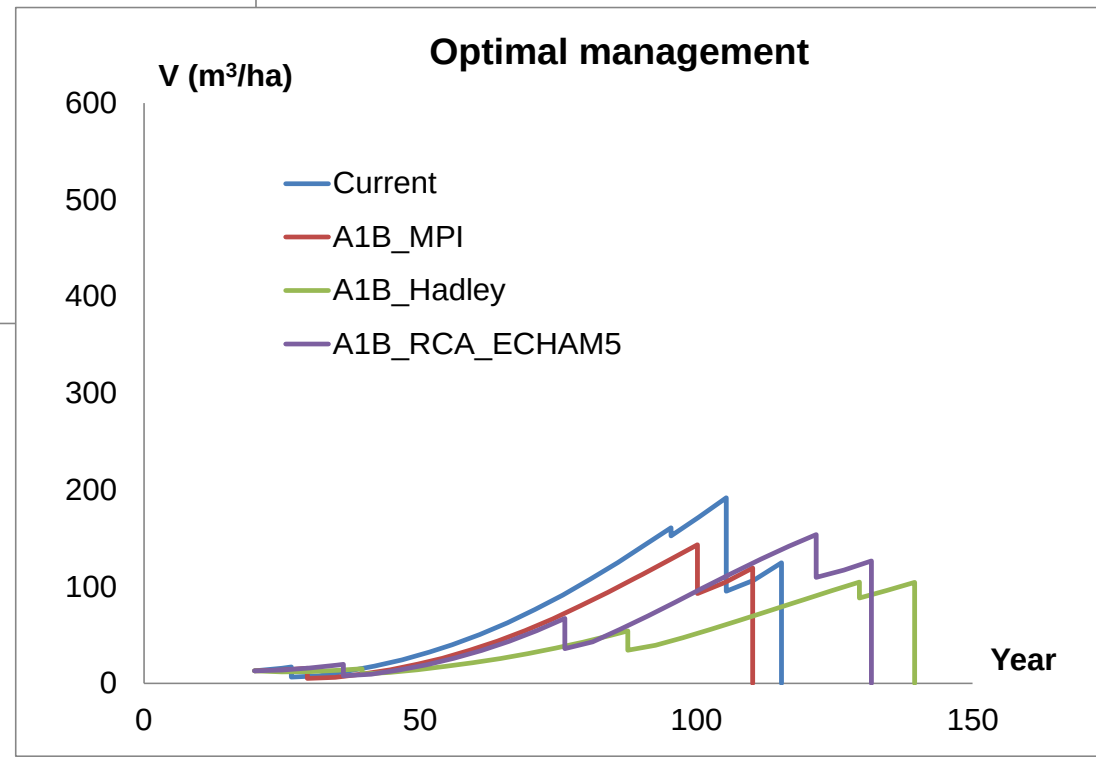


LEV2 (CHF/ha) WP (m ³ /ha*y)	MANAGEMENT OPTIMIZED FOR:				
REALIZED CLIMATE	CURRENT	A1B_MPI	A1B_HADLEY	A1B_RCA-ECHAM5	LOSS %
CURRENT	LEV2 = 1830.4 ; WP=3.5	LEV2 = 1638.3; WP=3.5	LEV2 = 1818.1; WP=3.5	LEV2 = 1792.6; WP=3.5	11.6 (192.1)
A1B_MPI	LEV2 = 2060.2; WP=3.8	LEV2 = 2067.8; WP=3.8	LEV2 = 1843.5 WP=3.8	LEV2 = 2051; WP=3.8	10.5
A1B_HADLEY	LEV2 = 3136.1; WP=5	LEV2 = 3221.6; WP=5.1	LEV2 = 3276.9; WP=5.2	LEV2 = 3229.3; WP=5.1	4.3
A1B_RCA_ECHAM	LEV2 = 2144.1; WP=3.9	LEV2 = 2186.2 WP=3.9	LEV2 = 1926.6; WP=3.9	LEV2 = 2215.2; WP=3.9	13

Drought: DI_Current = **0.67** (WHC = 71.4) ; GDD1_Current = 0.99



Extreme drought if A1B_Hadley scen. takes place, species change..



LEV2 (CHF/ha) WP (m ³ /ha*y)	MANAGEMENT OPTIMIZED FOR:				
REALIZED CLIMATE	CURRENT	A1B_MPI	A1B_HADLEY	A1B_RCA-ECHAM5	LOSS%
CURRENT	LEV2 = 64.1; WP=1.2	LEV2 = -2.5; WP=1.3	LEV2 = 64.1; WP=1.2	LEV2 = 64.1; WP=1.2	104
A1B_MPI	LEV2 = 55.1; WP=0.9	LEV2 = 295; WP=1.8	LEV2 = 55.1; WP=0.9	LEV2 = 55.1; WP=0.9	81.4
A1B_HADLEY	LEV2 = - 64.2; WP=1	LEV2 = -162; WP=1.1	LEV2 = - 64.2; WP=1	LEV2 = - 64.2; WP=1	152 (98)
A1B_RCA-ECHAM5	LEV2 = 167.3; WP=1.4	LEV2 = 121.3; WP=1.5	LEV2 = 167.3; WP=1.4	LEV2 = 167.3; WP=1.4	28

Conclusions

- Results show that in general climate change has a significant effect on optimal decisions (how extreme the extreme scenario is)
- Depending on the site conditions (climate x local site) for the stand the loss of assuming a wrong climatic scenario could be relevant – but may also be minimal
- Site types in which adaptation is more relevant can be identified and support provided to practitioners

Perspectives

Important prerequisite in place

- The flexibility of the climate sensitive growth model is essential for evaluating quickly several different management options under various climate scenarios

... allowing for more advanced modeling too:

- Flexibility in management over time; change management regime along rotation
- New algorithms should incorporate the effect of (Bayesian) updating about the climate state as information arise and allow for recognizing the actual climate realization
- The model allows for evaluating risks and other goods & services (stand structure); more complex objective functions
- Extend the model to mixed beech-Norway spruce-Fir stands (sp. sel.)