TEMPORAL AGGREGATION AND ITS INFLUENCE ON STRATEGIC FOREST MANAGEMENT UNDER RISK OF WIND DAMAGE

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Outline of the presentation

- Wind-damage in forestry
- Project objectives
- GMDP model
- Björnstorp estate
- Results
- Conclusions


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Project objectives

- Wind damage is a major concern in numerous countries due to the massive damage it afflicts
- Recent as well as earlier storms has had a major impact:
  - "Anathol, Lothar, Martin" – 1999 – damaged 200 Mm^3 of timber in western Europe
  - "Pyry, Janika" – 2001 – damaged 7 Mm^3 of timber in Finland
  - "Gudrun" – 2005 – damaged 70 Mm^3 of timber in Sweden
  - "Klaus" – 2009 – damaged 45 Mm^3 of timber in France
- In Europe, wind damages 18.5 million m3 of wood per year, accounting for more than 50% of all forest damages

Project objectives

- Silvicultural management influences a stands resilience to wind damage
  - Selection of tree species
  - Earlier and less intensive thinning
  - Earlier clear-cutting
  - Avoiding the creation of new unprotected edges
- However, risk of wind damage is commonly not considered when developing long-term strategic forest management policies
- Can the value of an estate be increased by long-term management according to risk of wind damage?

Project objectives

- Large models are required for optimizing long-term management policies under wind damage
  - Stochastic damage events
  - Spatial dependencies between stands
- Time is commonly aggregated according to discrete time periods
  - Longer time periods → approximate but smaller problem to solve
  - Shorter time periods → less approximate but larger problem to solve
- What is the influence of the temporal aggregation?

Project objectives

- Main aim of project:
  - Analyze the value of considering the risk of wind damage in long-term forestry planning
  - Analyze the influence of the length of considered time periods
- Utilize a model that considers:
  - Spatial dependencies between stands
  - Stochastic damage events
  - Can consider large and diverse estates
- Perform a case study of an estate in Sweden

GMDP model

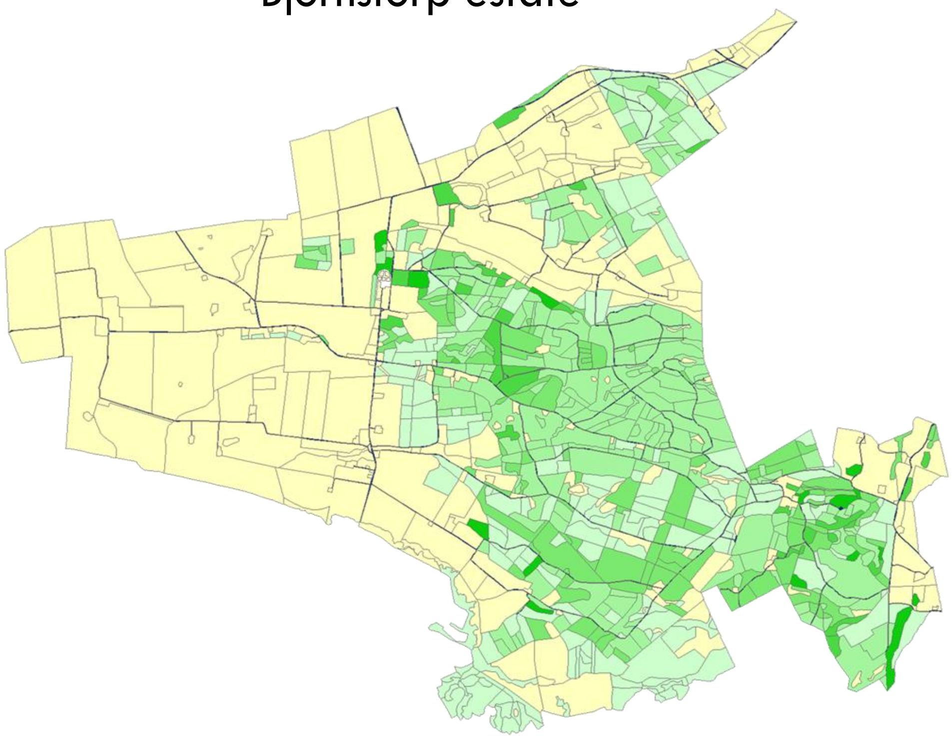
- Components of the Graph-based Markov Decision Processes (GMDP) model:
  - G : Graph structure specifying location and dependencies between stands
  - $S = (S_1,\ldots, S_n)$: A state variable S_i for each stand *i*, specifying the possible age of the stand ($S_i=\{1, 2, 3, 4, 5\}$)
  - $A = (A_1,\ldots, A_n)$: A action variable A_i for each stand *i*, specifying the possible management of the stand ($A_i=\{1, 2\}$)
  - $P(S' \mid S,A) \rightarrow \mathfrak{R}$: Transition function defining the probability of a stand changing from a state to another state
  - $R(S,A) \rightarrow \mathfrak{R}$: Reward function specifying the revenue by performing a management in the stand

GMDP model

- Finding the optimal management policy corresponds to computing the policy (*M*) that gives the highest expected NPV of the estate :
  - $M(S) \longrightarrow A$: Policy specifying which actions (management) should be performed in the stands depending on their state
- Stands managed according to fixed and variable management activities:
  - Fixed: Soil preparation, planting, thinning, pre-commercial thinning
  - Variable: Clear cutting
- An Approximate Linear-Programming (ALP) algorithm was used to compute an near-optimal policy

Björnstorp estate

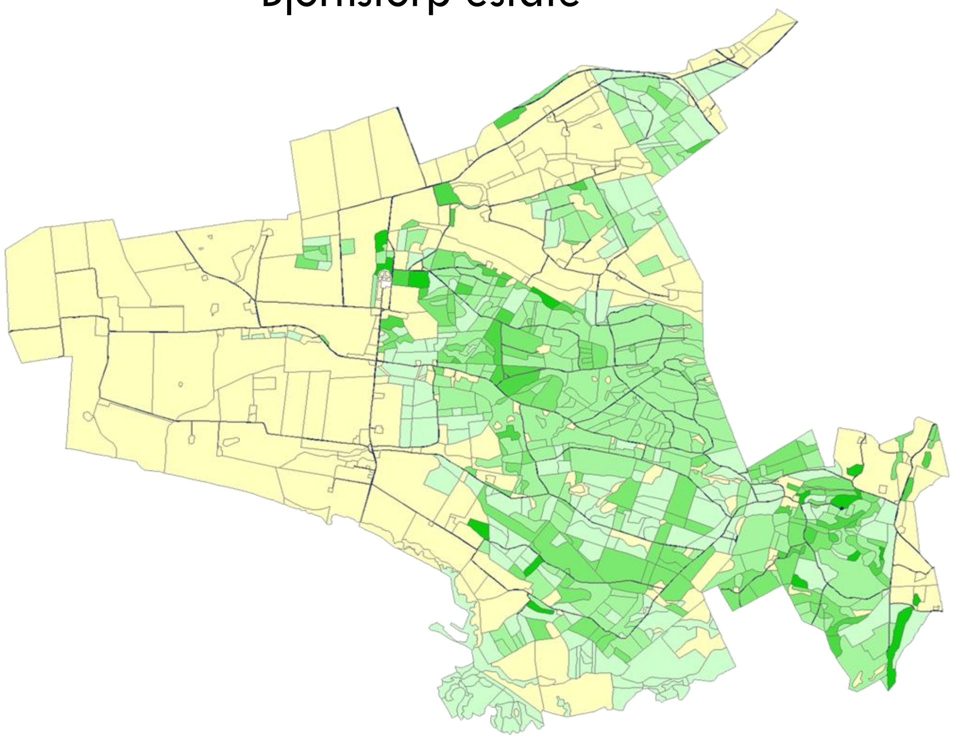
- The estate is located in the southern parts of Sweden
  - 2800 ha of land
  - 1200 ha of forestry land
  - 623 stands
- Estate is mainly dominated by Norwegian Spruce
- Diverse age and state of stands



Björnstorp estate

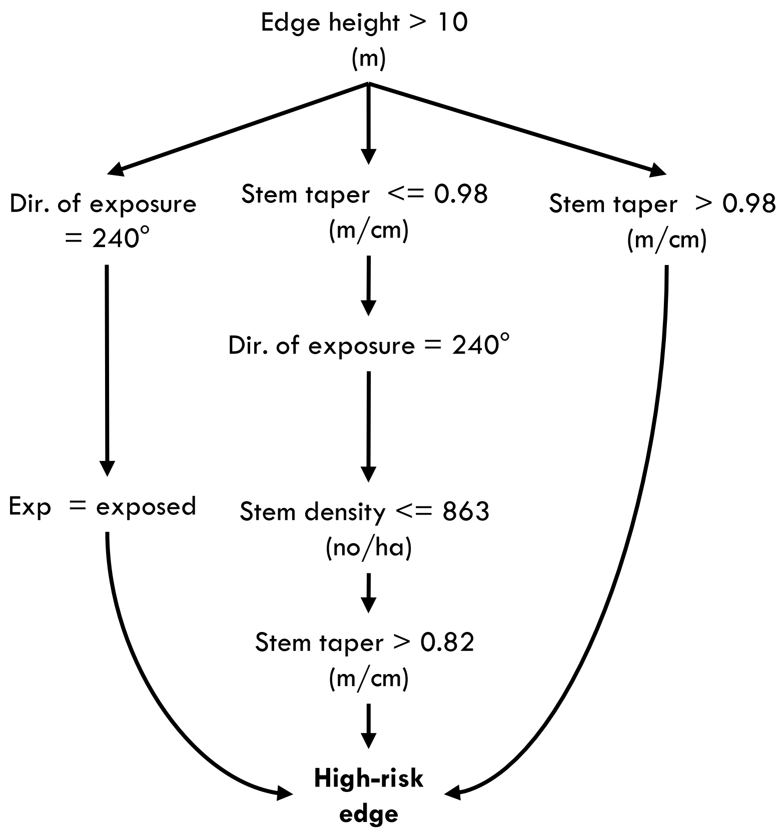
- Three GMDP models of the estate was created according to different length of time periods:
  - 20-years
  - 10-years
  - 5-years
- For each model, two management policies were computed:
  - Wind management
  - No-wind management

Björnstorp estate



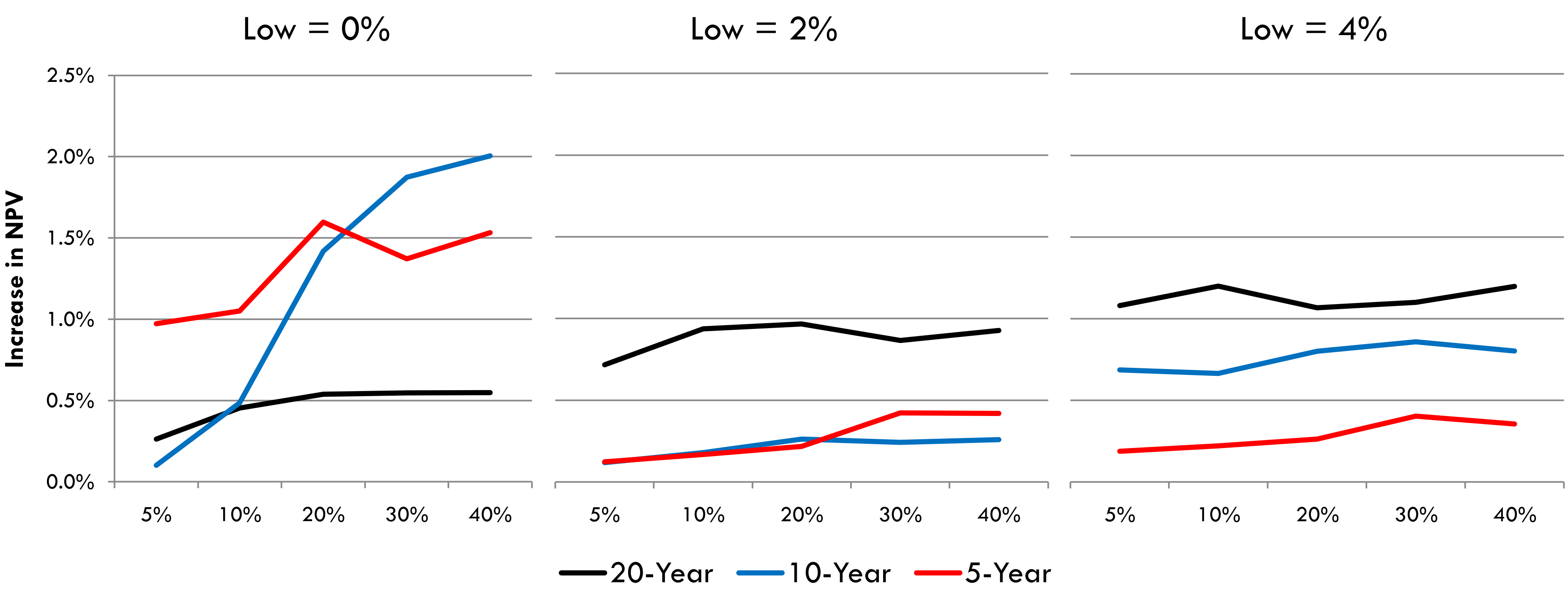
Björnstorp estate

- Revenue of management was estimated with Swedish growth-and-yield simulator
- A step-wise evaluation tool was used to evaluate if a stand had:
  - Low-risk of wind damage (<5%)
  - High-risk of wind damage (≥5%)



Results

- Increase in NPV of estate by managing it according to risk of wind damage (whole estate)



Results

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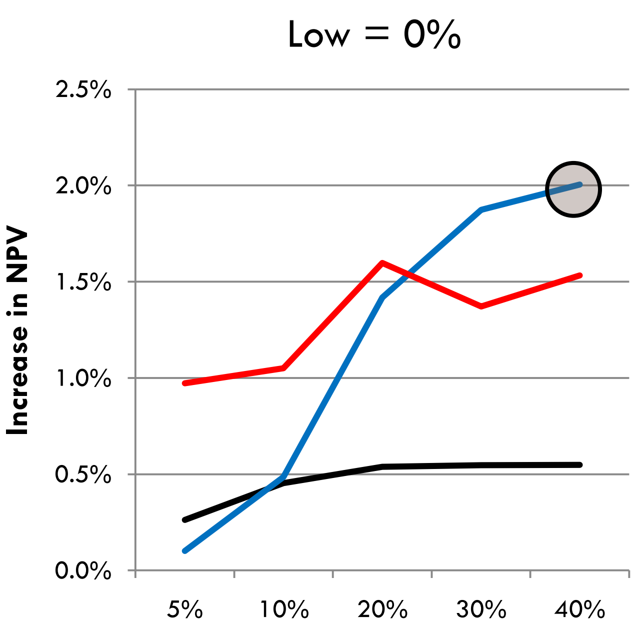
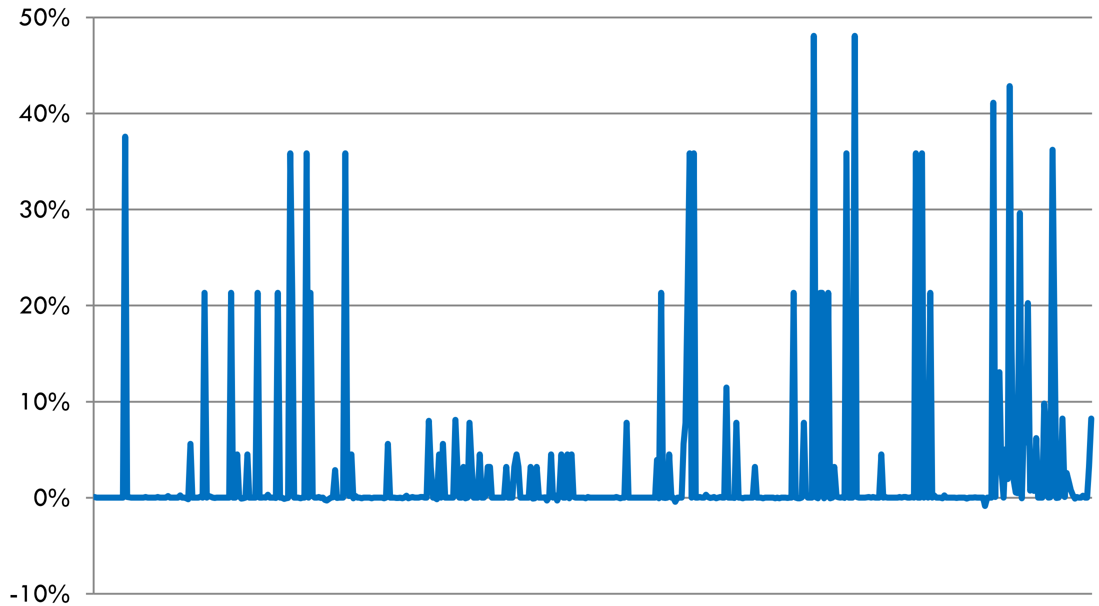
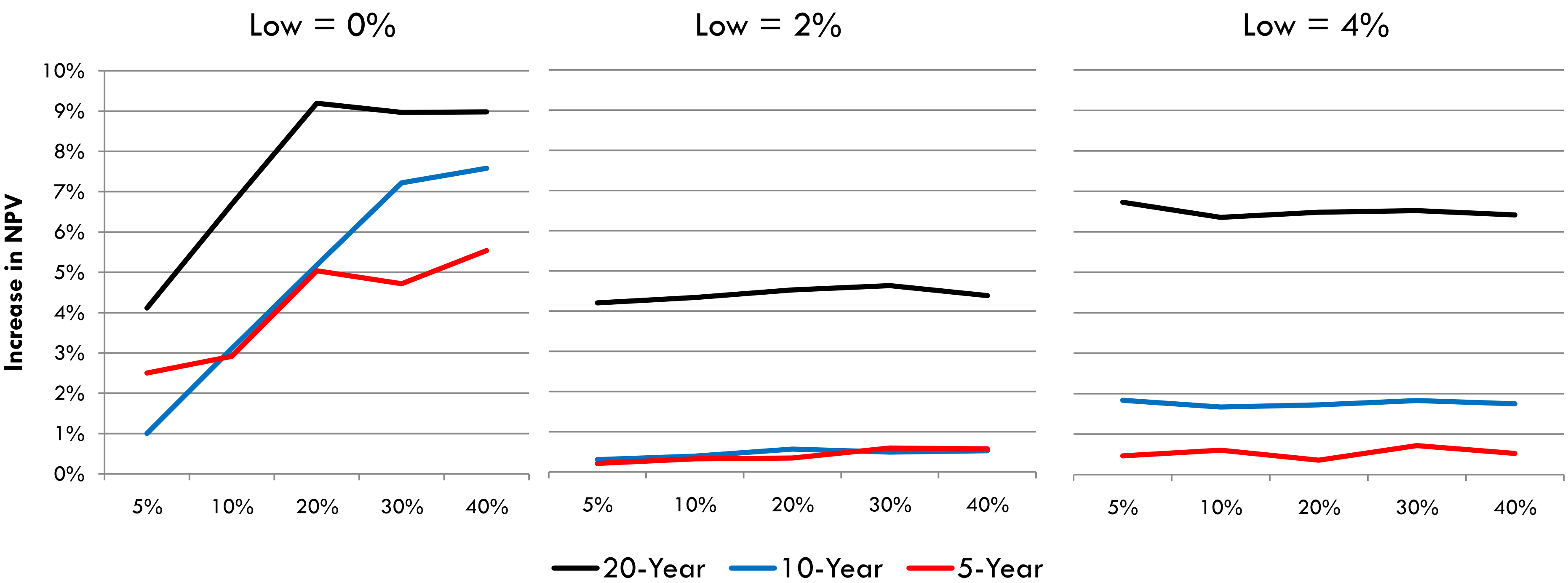




Results

- Increase in NPV of estate by managing it according to risk of wind damage (stands managed differently between wind and no-wind)



Conclusions

- Risk of wind damage can be integrated in spatial long-term strategic forestry management
- Adapting the clear-cutting age according to risk of wind-damage only slightly increase the NPV of the estate (<2%)
- Length of time periods has an influence on results

Conclusions

GMDP model

- Components of the model (G, S, A, P, R, M):
  - G : Graph specifying location and dependencies between stands
  - $S = (S_1,\ldots, S_n)$: A state variable S_i for each stand i, specifying the possible age of a stand (S_i={1, 2, 3, 4, 5})
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  - $M(S) \rightarrow A$: Management policy specifying which management should be performed in the stands

GMDP model

- A Graph-based Markov Decision Processes (GMDP) model was used to compute near-optimal management strategies:
  - Considers stochastic damage event (according to a know probability)
  - Management of stands according to fixed and variable management alternatives
  - Management of stands according to length of time periods