Decision Analysis in environmental management – Experiences from real-life cases

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Finnish Environment Institute (SYKE)

Course on Decision Analysis (MS-E2135)
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Outline of the presentation

- My background
- A bit about Finnish Environment Institute (SYKE)
- Planning of the Multi-Criteria Decision Analysis (MCDA) process in practice
  - Note: In this presentation MCDA is used as an umbrella term for structured DA processes applying Multi-Criteria Value Theory (MAVT) or some similar method
- Presentations of real-life cases in which decision analysis (DA) has been applied:
  1. Restoration alternatives of River Tourujoki in Central Finland
  2. Peatland rewetting in Tampere Kintulammi
  3. Peatland conservation in southern Finland

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My background

- **1996–2007: Research assistant/researcher** (Systems Analysis Laboratory, Aalto University)
  - M.Sc. on developing decision support system Web-HIPRE
  - Ph.D.(Tech) on developing MCDA tools and processes for practical applications
- **2008: Consultant/researcher** (100Gen Oy)
  - Environmental projects for SYKE related to the application of DA
- **2009–2012: Postdoctoral Researcher** (Department of Automation Science and Engineering, Tampere University of Technology)
  - Methodological MCDA related research
- **2012– : Senior researcher** (Freshwater Centre, SYKE)
  - Application of MCDA in real life cases

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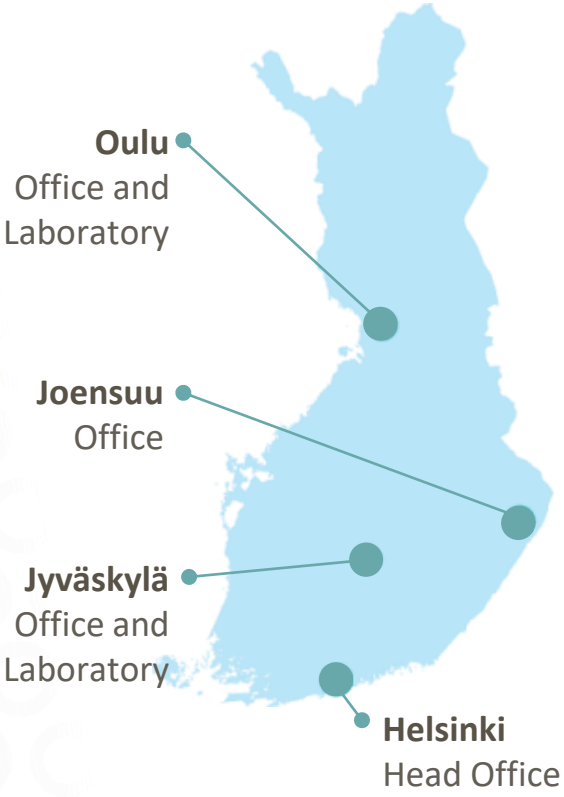
About SYKE



- Nature
- Water
- Consumption and Production
- Climate Change
- Sea
- Environmental Information
- Built Environment
- Urbanisation
- Circular Economy

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Our Vision and Mission

Vision
Sustainability transformation!
It is a turn reforming the systems of our society.

Mission Statement
SYKE supports the building of a sustainable society with research, information and services.

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Our Objectives

- We enhance climate change mitigation and adaptation.
- We advance the transition to a sustainable circular economy and bioeconomy.
- We support urban areas on their way to becoming forerunners of sustainability.
- We promote well-being through nature-based solutions and prevent biodiversity loss.
- We develop new approaches for reaching a good state of the seas and inland waters and achieving sustainable use of water resources.

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Personnel and Funding 2021

689
Personnel

63,8 M€
Total Funding

27,5 M€
Direct Budgetary Funding

36,3 M€
External Funding (56%)

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Systems analysis at SYKE

- **Environmental problems are typically very complex**
  - Do not only deal with complex environmental interactions, but also social and economic ones
  - Expertise is needed for modelling of these to support informed decision making
- **Systems analytical methods including DA are widely applied in SYKE**
  - Cyclic material and energy flow models, dynamic nutrient flow models
  - Life cycle impact assessment
  - Decision analysis to support participatory environmental management
  - Carbon sequestration and balance models
  - Optimal control models, simulation, Bayesian modelling, etc.
- Six doctors graduated from SAL work at SYKE (now or at a time of the dissertation)

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Planning of the Multi-Criteria Decision Analysis process in practice

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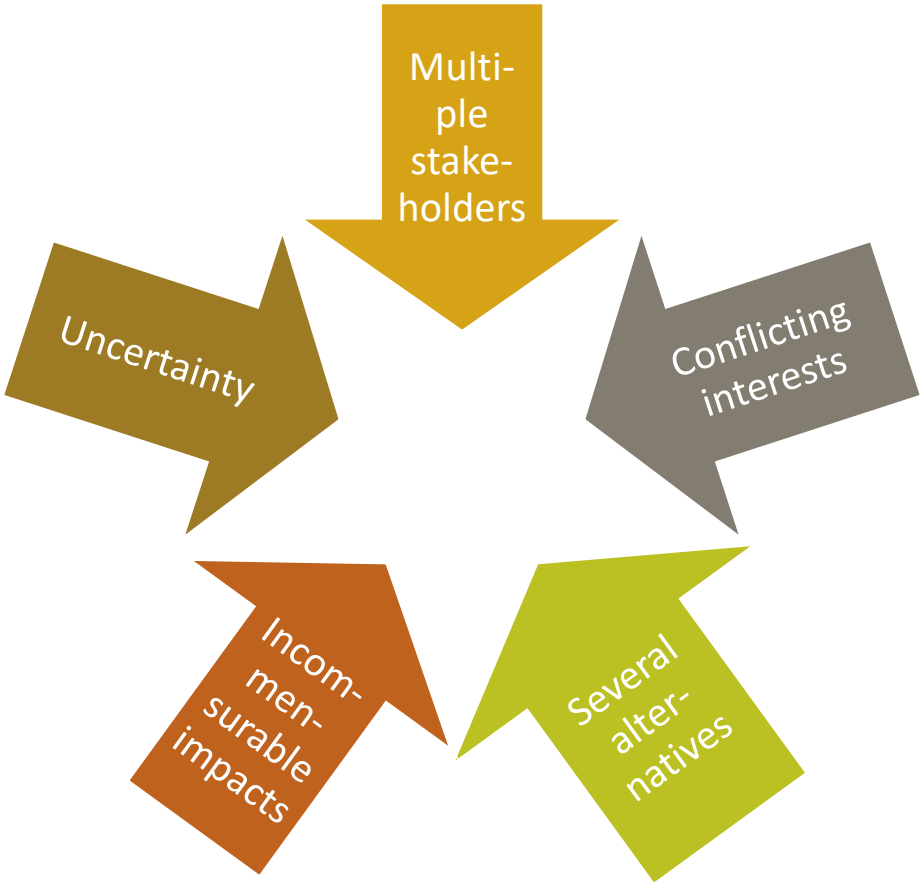
Properties of complex environmental problems



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Need for structured and transparent processes increasing

- Need for integrated environmental management
  - Comprehensive planning and implementation approaches are needed for managing environment in a way that
    - balances social and economic needs
    - ensures the protection of ecosystems for future generations
  - **What kind of approaches and tools can best support the process?**
- Need for science-policy interaction
  - Decision makers, researchers and stakeholders seek together solutions to complex environmental problems
  - **How to improve the dialogue between different actors and the use of research results in policy making?**

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How can MCDA help to deal with complexity?

- A **structured process** to identify objectives, create alternatives and compare them from different perspectives
  - *"Well structured is half solved"*
- Based on **value-focused thinking** (Ralph Keeney)
  - Avoids "my alternative" vs. "your alternative" debate
- Aim to improve the quality of decisions by making choices more **transparent, rational and efficient**
  - People prone to systematic errors in their judgments
- **Helps** individuals or groups to analyze alternatives having multiple and incommensurable impacts
  - *"People make the decision, not the model"*
  - *"Learning by analyzing"*

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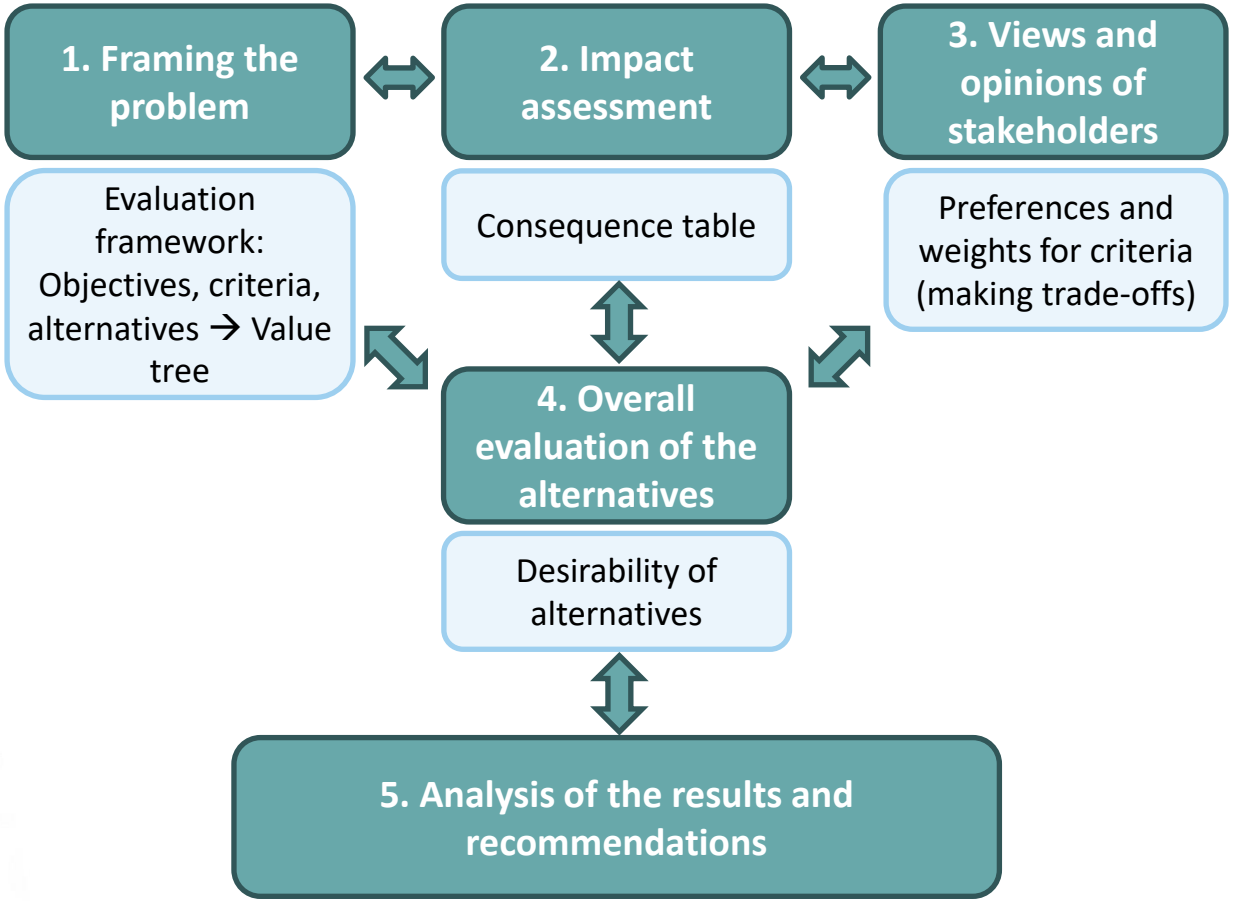
Typical realization of the MCDA process



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Different ways to apply MCDA

”Problem structuring tool”

Structured and systematic identification of stakeholders’ objectives, building common evaluation framework and developing alternatives

”Synthesizing and modelling tool”

Combining diverse information and calculating rank order to alternatives

”Consensus building/conflict management tool”

Supporting stakeholder involvement, participants’ learning and solution finding

”Science-policy interaction tool”

Structuring the problem, joint fact finding, development of alternatives, identification of key trade-offs

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Advantages and challenges of MCDA

Advantages

- Promotes value-focused thinking
- Helps to get a structured view of the problem and to make trade-offs between the criteria
- Makes it possible to combine factual data with the values of the stakeholders
- Helps to visually understand the reasoning behind the ranking of the alternatives

Challenges

- Possibility of behavioral biases
  - How to make sure that the stakeholders' weights reflect their 'true' preferences?
  - The structure of the model and the applied methods can affect the weights and the results
- It is easy to get 'good-looking' result, even if the stakeholders haven't fully understood the method

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Levels of interactivity in the environmental management projects

Level	Interaction in the project
Very high	- Joint analysis and problem solving by experts and stakeholders - Strong sense of shared ownership - Long-term implementation structures
	- Stakeholders are consulted and informed from the early phases of the project - Stakeholders participate to the identification of objectives, development of the alternatives, impact assessment and making recommendations
	- Stakeholders' and citizens opinions are asked in the different phases of the project, for example in public hearings and postal questionnaires
Very low	- The project is realized by the experts - Stakeholders and citizens are informed about the project

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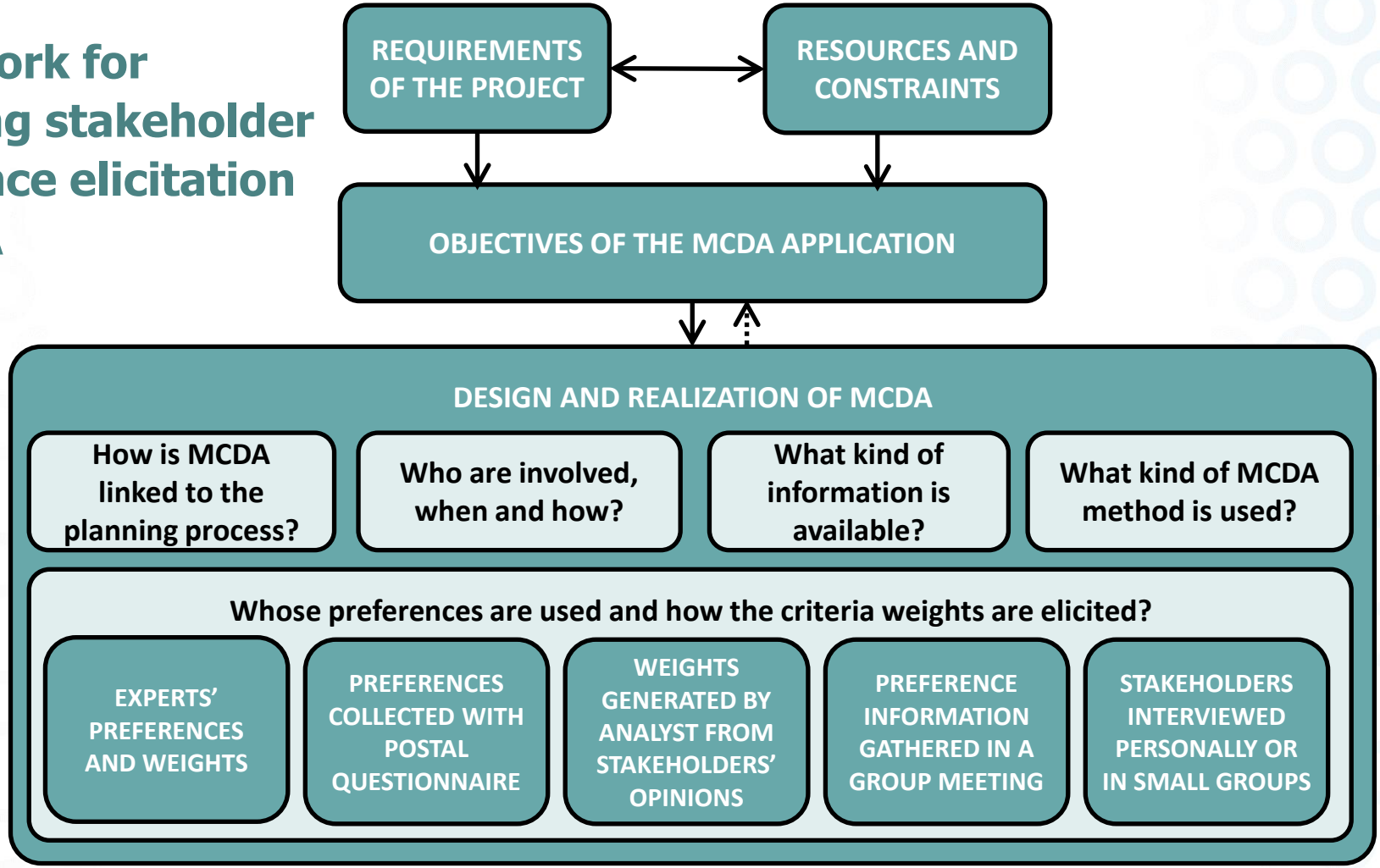
Framework for designing stakeholder preference elicitation in MCDA



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Advantages and challenges of participatory approaches

Advantages

- Social learning
  - Experts learn from stakeholders and vice versa
- Local knowledge

  → Improved quality of the outcome
- Creates commitment to the outcome
  - Solutions are more acceptable

Challenges

- Deciding who are engaged into the process
- Deciding what information can be presented to participants
  - Understandability and avoiding misinterpretation, if preliminary data (which may change in the later phases) is presented
- Time consuming

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Case 1: Restoration of River Tourujoki

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Case: Restoration of River Tourujoki

Problem	- An urgent need to **collect, analyze and structure** information about **the river restoration alternatives** related to the development of a **new residential area**
	  - 5 000 habitants in the Centre of City of Jyväskylä
	  - A small hydro power plant on the river
	  - Suggestions to build a recreational by-pass channel on the river
	- Locally a very controversial issue:
	  - "Enhancing river biodiversity and reproduction of lake trout" vs. "Minimizing costs and risks, maintaining hydropower production"

Time	1/2014–3/2014
Problem owner	City of Jyväskylä
Stakeholders/ participants	- Committee of urban structure, Steering group of the Tourujoki project, group of local stakeholders as stakeholders (42 people altogether) - Public through web questionnaires - City Council as a decision maker

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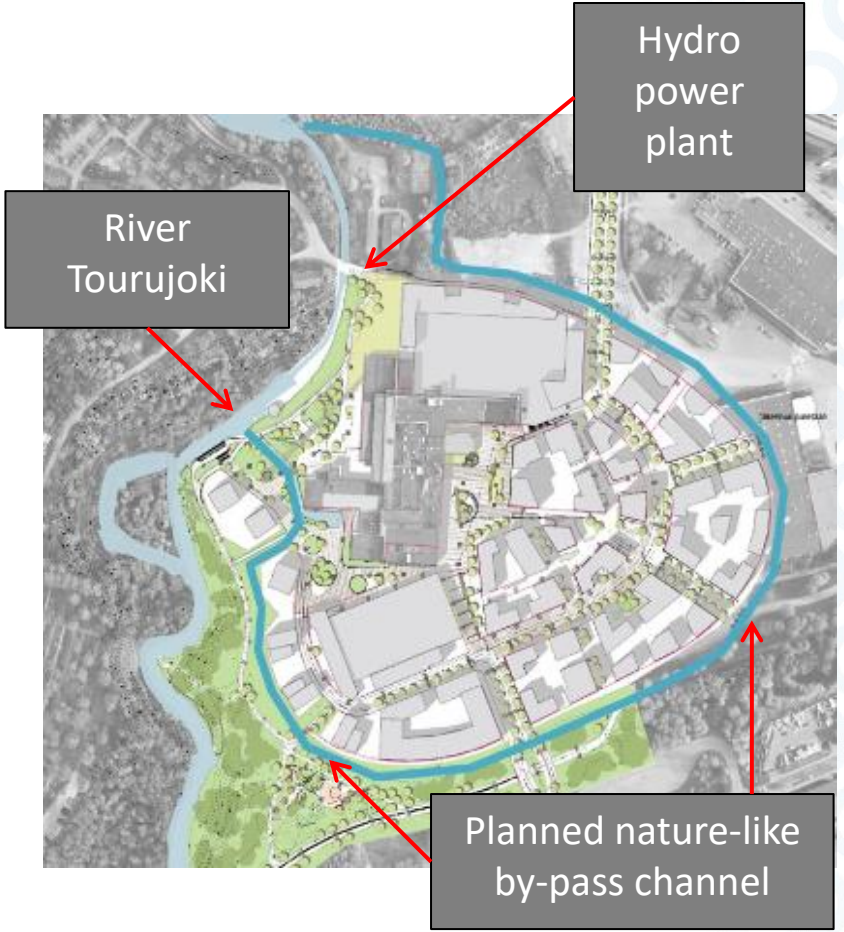
River Tourujoki

Photo: Juan Ramirez

Map of the area



Selection of DA approach

Characteristics of the problem	- Very tight timetable – Not possible to make e.g. time-consuming decision analysis interviews - Some data already available, for example, about the costs of the alternatives - Very closely related to the political decision making - Aim to provide knowledge for informed decision making

Selected weight elicitation approach	**Weights generated by analysts from stakeholders' opinions**
	- Basic MAVT approach based on
	  - creating preference profiles of different stakeholders as an expert work, and
	  - demonstrating how the results change among stakeholders
	- Use of bar graphs to visualize the pros and cons of different alternatives

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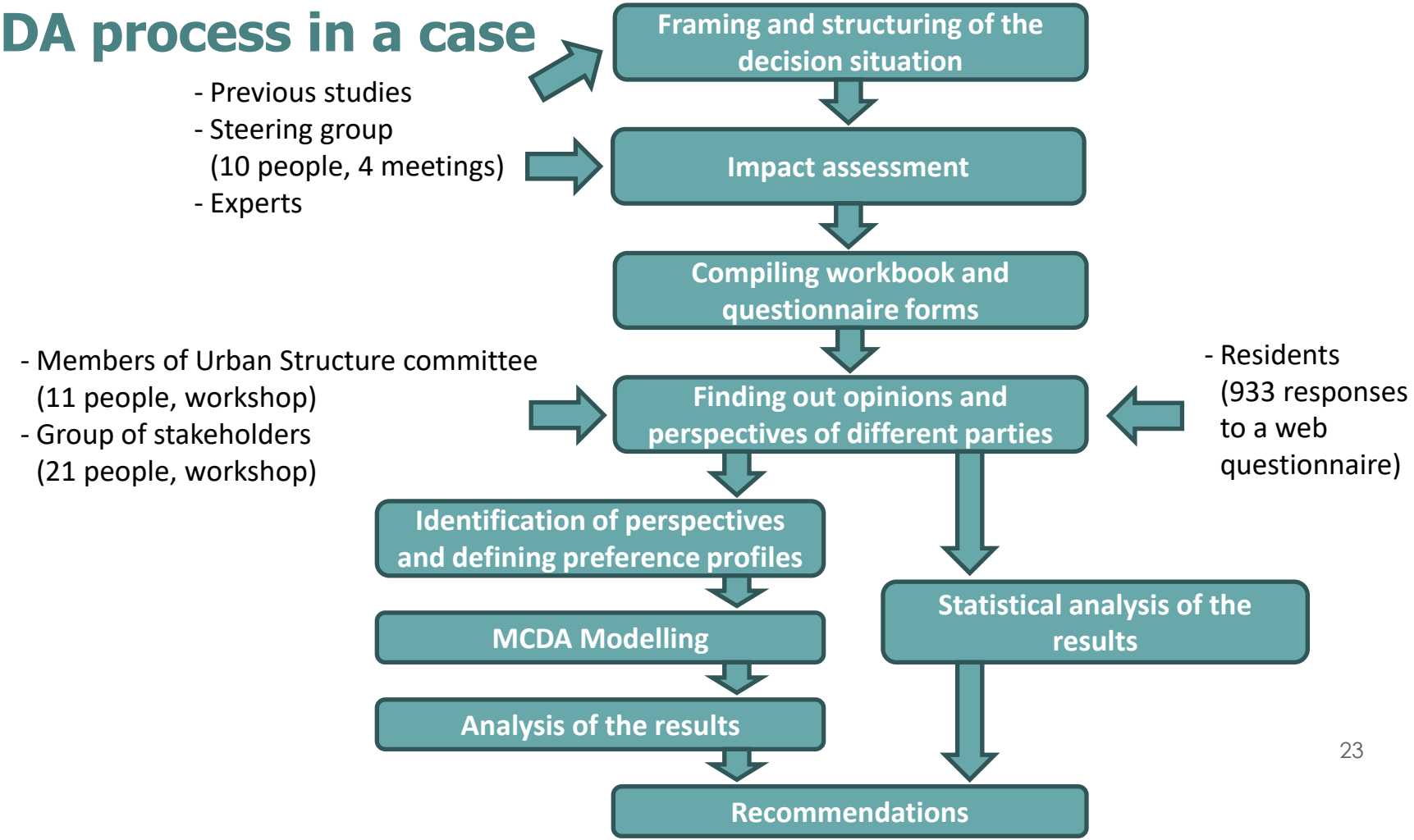
MCDA process in a case

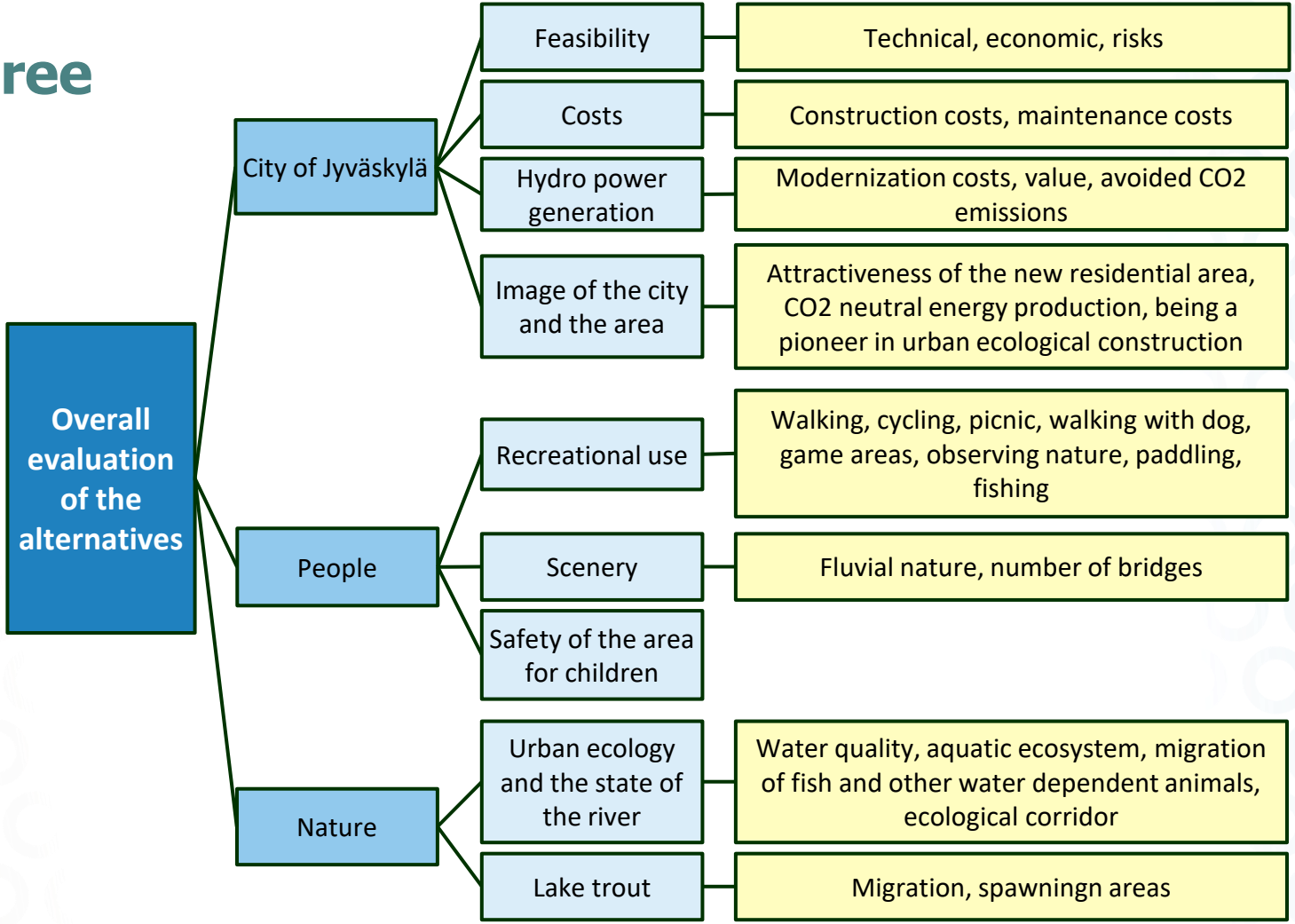
- Previous studies
- Steering group
  (10 people, 4 meetings)
- Experts



- Members of Urban Structure committee
  (11 people, workshop)
- Group of stakeholders
  (21 people, workshop)

- Residents
  (933 responses to a web questionnaire)

Value tree



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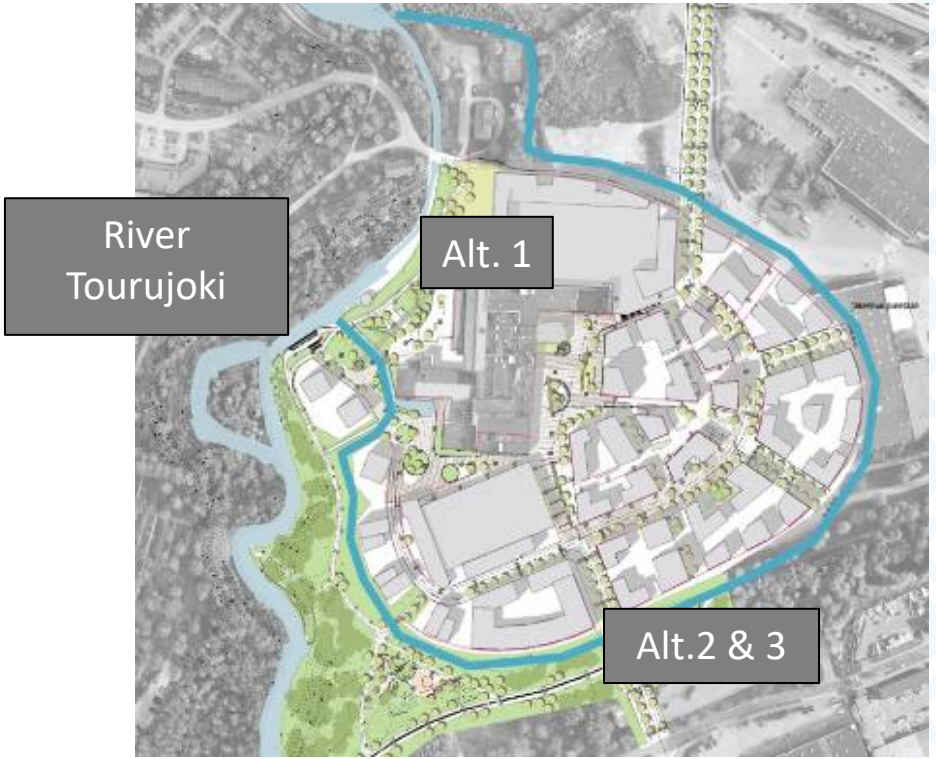
Alternatives

- **Four alternatives** to compare:
  - **Alt. 0+**: Slightly improved status quo
  - **Alt. 1**: Technical fishway
  - **Alt. 2**: Small nature-like bypass channel
  - **Alt. 3**: Larger nature-like bypass channel



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Criteria weights

- **Four different stakeholder perspectives**, i.e. weight profiles (WP) generated by project experts on the basis of the workshop results and public web questionnaires:
  - **WP1**: “Trout and nature”
  - **WP2**: “Recreational use”
  - **WP3**: “Green energy and climate”
  - **WP4**: “Costs”

  → Analysis of what are the best alternatives from different viewpoints and evaluation of the pros and cons of the alternatives in a common framework
    - Can be considered as a kind of a sensitivity analysis

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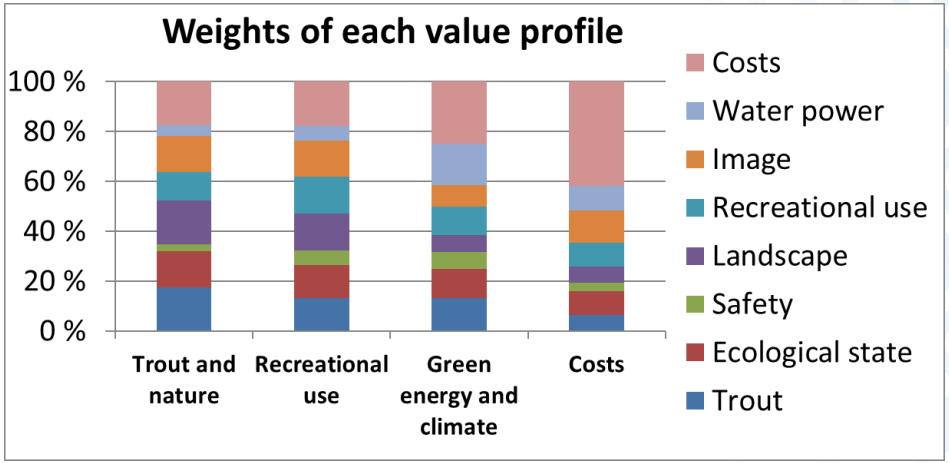
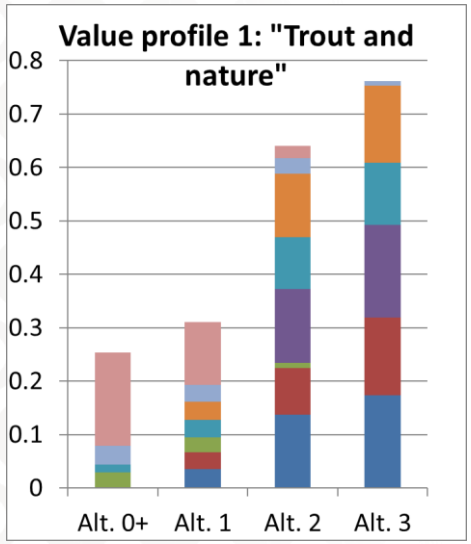
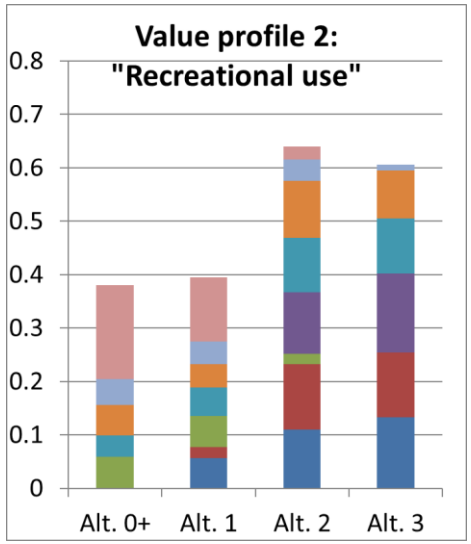
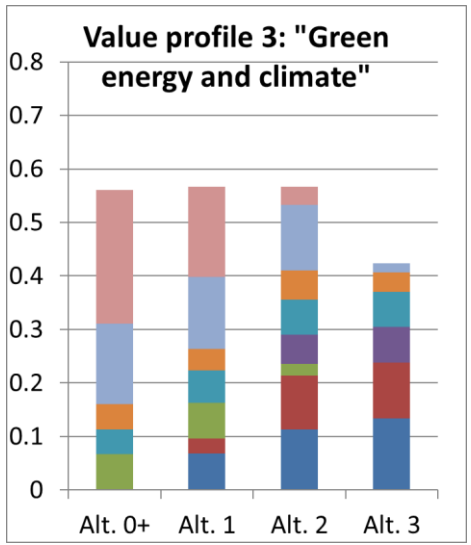
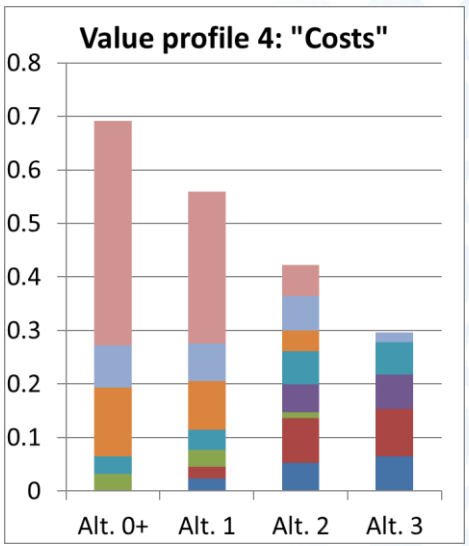
Weights of each value profile and corresponding values of the alternatives











Weights generated by analysts from stakeholders' opinions

Advantages

- Risk for stakeholders' behavioral biases and mistakes is minimized
- Less laborious than interactive preference elicitation methods, but still presents a variety of preferences
- Enables sensitivity analysis with respect to stakeholders' estimated preferences

Challenges

- Do value profiles describe the people's perspectives correctly?
- Do stakeholders accept the generated views, or do they consider the results manipulative?
- Experts may intentionally generate value profiles that produce the results they want

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Outputs and use of the results

Outputs	- Overall values of different options from four different viewpoints:
	  - "Trout and nature"
	  - "Recreational use"
	  - "Green energy and climate"
	  - "Costs"
	- Structured analysis of the issues of agreement/disagreement
	- A report for the City Council about the analysis

Use of the results	- Helped to assess the River Tourujoki development options in an impartial, fair and transparent assessment process
	  - Comparison of weight profiles helped to make the impacts of the different options visible for the citizens
	- Helped to produce information in a structured format about the options and their impacts for municipal decision making
	  - The final decision was left for City Council of Jyväskylä

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Case 2: Peatland rewetting in Tampere Kintulammi

Photo: Laura Venzo, Visit Tampere

Case: Peatland rewetting in Tampere Kintulammi

Problem	- City of Tampere owns a very popular recreational/nature reserve area of Kintulammi
	  - Hiking destination of the year 2020 in Finland
	- Plenty of drained peatlands in the area → Rewetting of these would restore them to their original state
	- City is preparing a management and use plan for the area
	  - **Which peatland stands should be rewetted first?**

Time	1/2020–3/2020
Problem owner	City of Tampere – Nature services Funded as part of academy research project
Stakeholders/ participants	Altogether 15 representatives from - Different units of the City of Tampere - Local nature protection association - Pirkanmaa Centre for Economic Development, Transport and the Environment - Company responsible for the recreational infrastructure in the area

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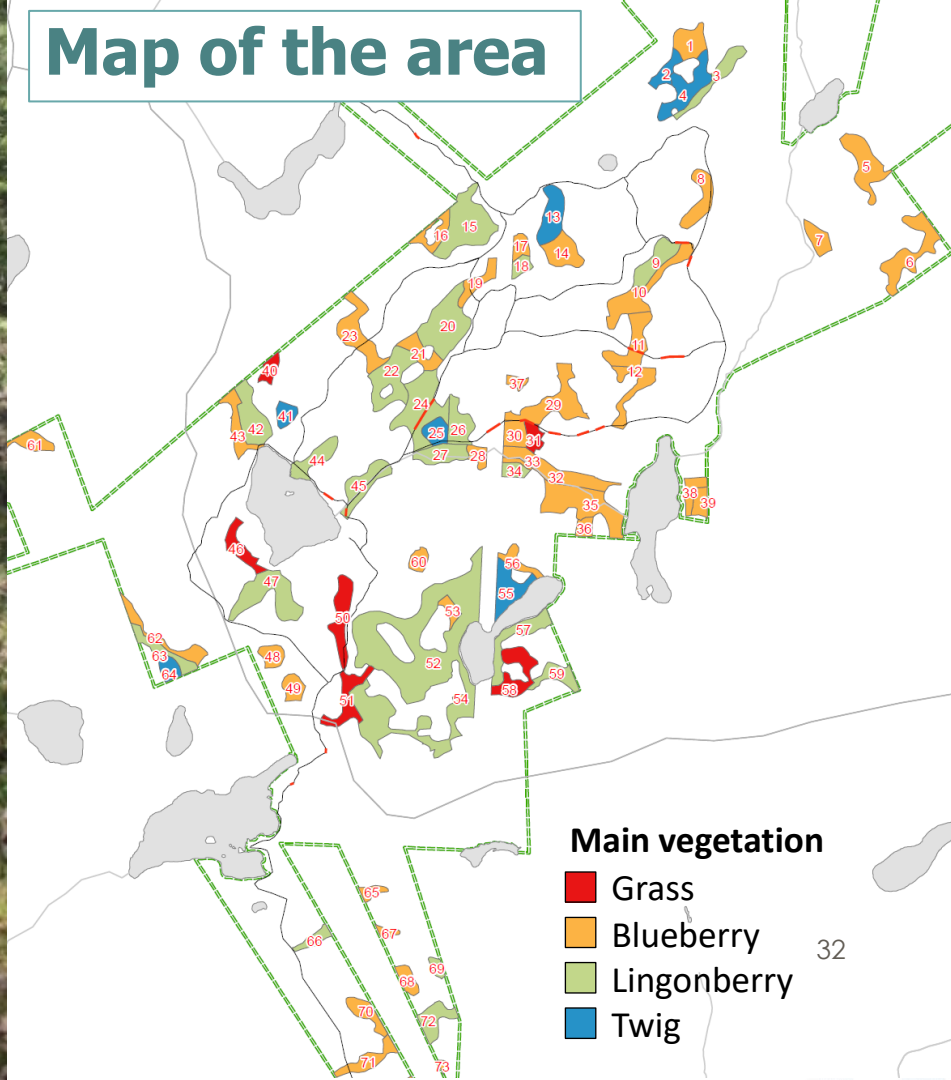
Ditched peatland at Kintulammi

Photo: Jyri Mustajoki

Map of the area



Selection of DA approach

Characteristics of the problem	- A typical portfolio problem
	  - Tens of alternatives (79 peatland stands from 0.1 to 15 ha)
	  - Only possible to rewet some of them due to resource constrains
	- Impact data available from previous project
	  - Problem (including criteria and alternatives) partly fixed
	- Tight time frame – Rewetting had already partly started
	- The project was funded by Academy of Finland which made methodological testing possible

Selected weight elicitation approach	**Preferences gathered in a workshop under the guidance of the decision analyst**
	- Two workshops and expert work within a two-month period
	- Three different DA/PDA (Portfolio Decision Analysis) methods:
	  - MAVT (Multi-Attribute Value Theory)
	  - RPM (Robust Portfolio Modeling)
	  - YODA (Your Own Decision Aid)

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Applied methods

- **MAVT (Multi-Attribute Value Theory)**
  - Helps to structure information about the effects of different options
  - Takes into account the perspectives of different stakeholders with weights assigned to different criteria
- **RPM (Robust Portfolio Modelling)** developed in Aalto University
  - Extends MAVT to portfolio problems
  - Helps identify a subset of peatland stands that produce the greatest overall benefit withing the constraints set (here the area to be restored)
- **YODA (Your Own Decision Aid)** developed in Luke
  - Helps to find the best overall solution by allowing the decision maker to adjust the feasible bounds for each criteria
  - Based on this the unfeasible options are eliminated

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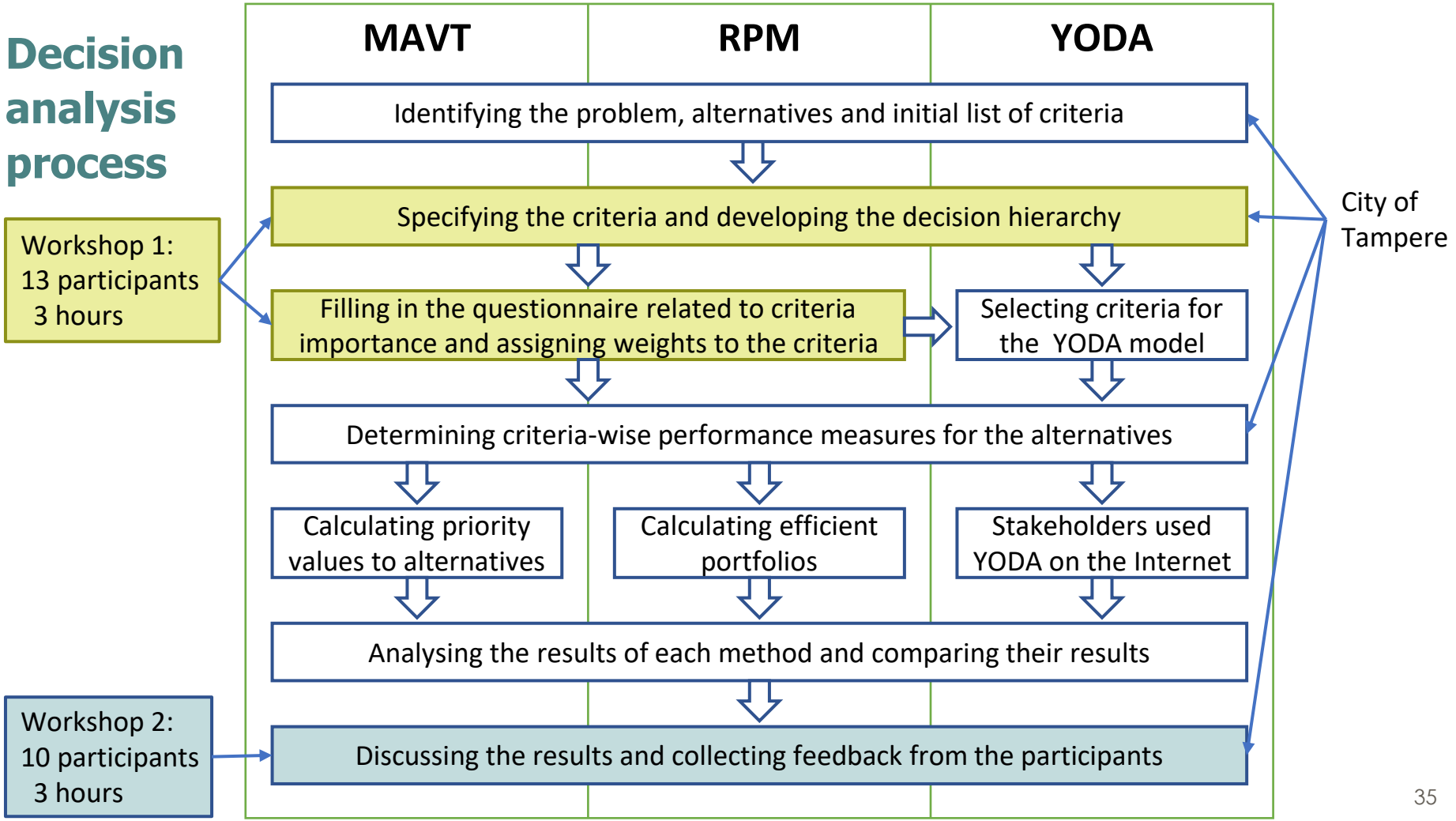
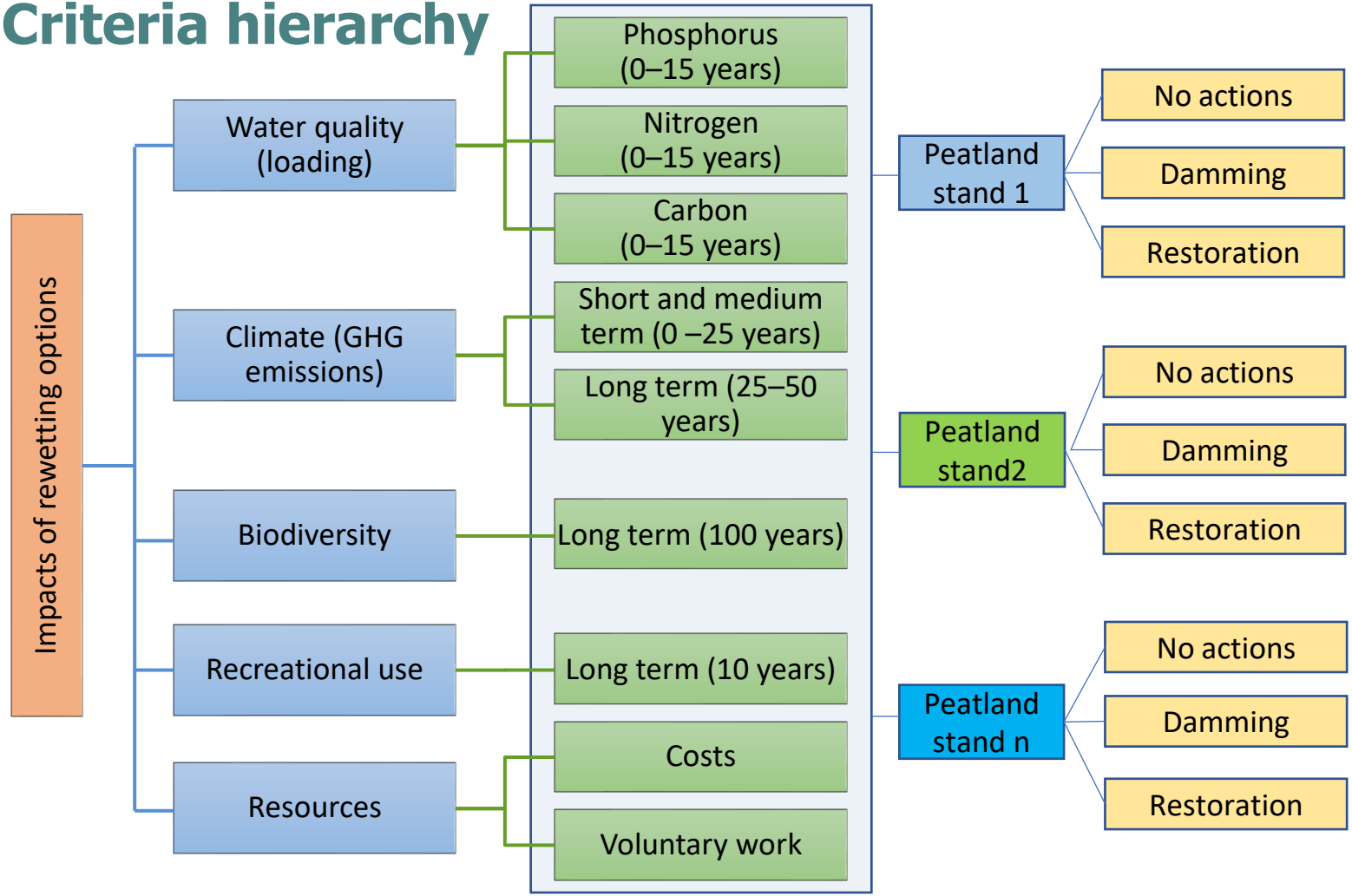
Decision analysis process



Criteria hierarchy



No action:
Do nothing

Damming:
Building the dam to the lower end of the stand and letting the nature to take care of the rest

Restoration:
Filling of the ditches and cutting of the trees

Weighting process

- Questionnaire in which the impacts of alternatives to different criteria were described
  - The impacts of the best and worst possible alternatives were described
  - Scales of the impacts were illustrated by providing references to other instances
    - E.g. CO_2 emissions were compared to the emissions of an average Tampere citizen
- Filling in questionnaire with (modified) Swing method
  - Participants asked to give 100 points to the most important criterion in terms of the difference between the best and worst alternatives
  - Then 0–100 points to other criteria describing their relative importance

  → Weights obtained by normalizing the sum of points to one
  - Project persons were available to help participants all the time

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Preferences gathered in a workshop under the guidance of the decision analyst

Advantages

- Less laborious than personal interviews
- New information and perspectives of other people may broaden participants' views and affect their preferences
- People are encouraged to think about their values and objectives more than normally

Challenges

- Some people may have difficulties in following the facilitator's guidance in the workshop
- Difficult to ensure that people understand the questions in the right way
- Not possible to identify biases in preference elicitation
- Difficult to estimate the time needed

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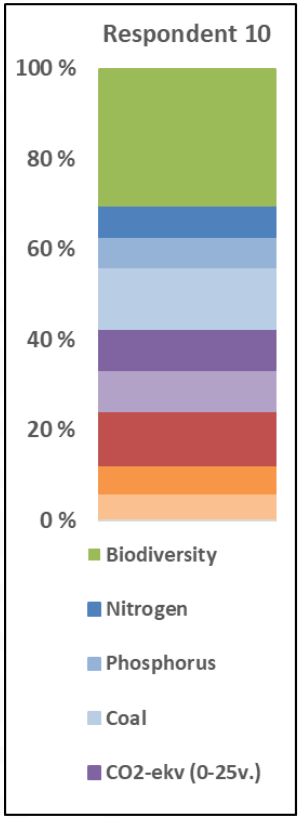
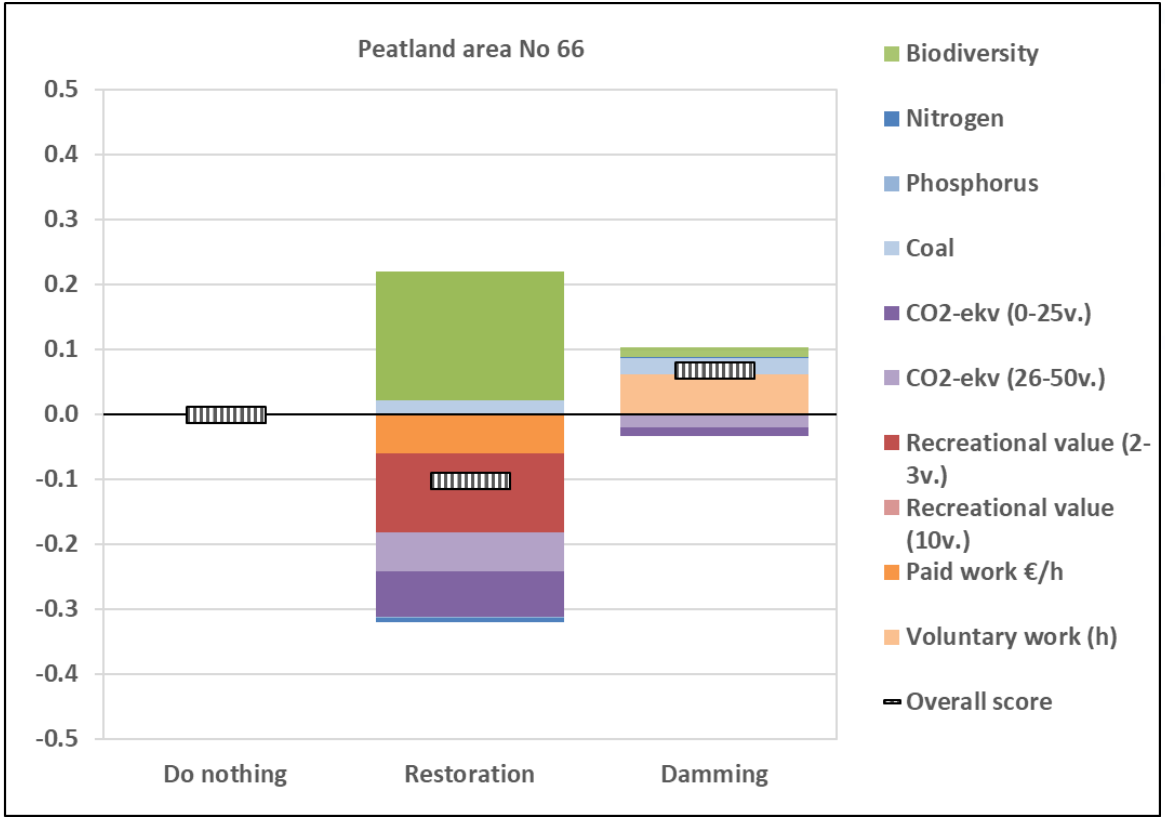
Results of MAVT

Analysis of a single peatland stand for any respondent's weight set (13 + median)

- Interactive Excel, in which possible to select the results of any weight set for any peatland stand





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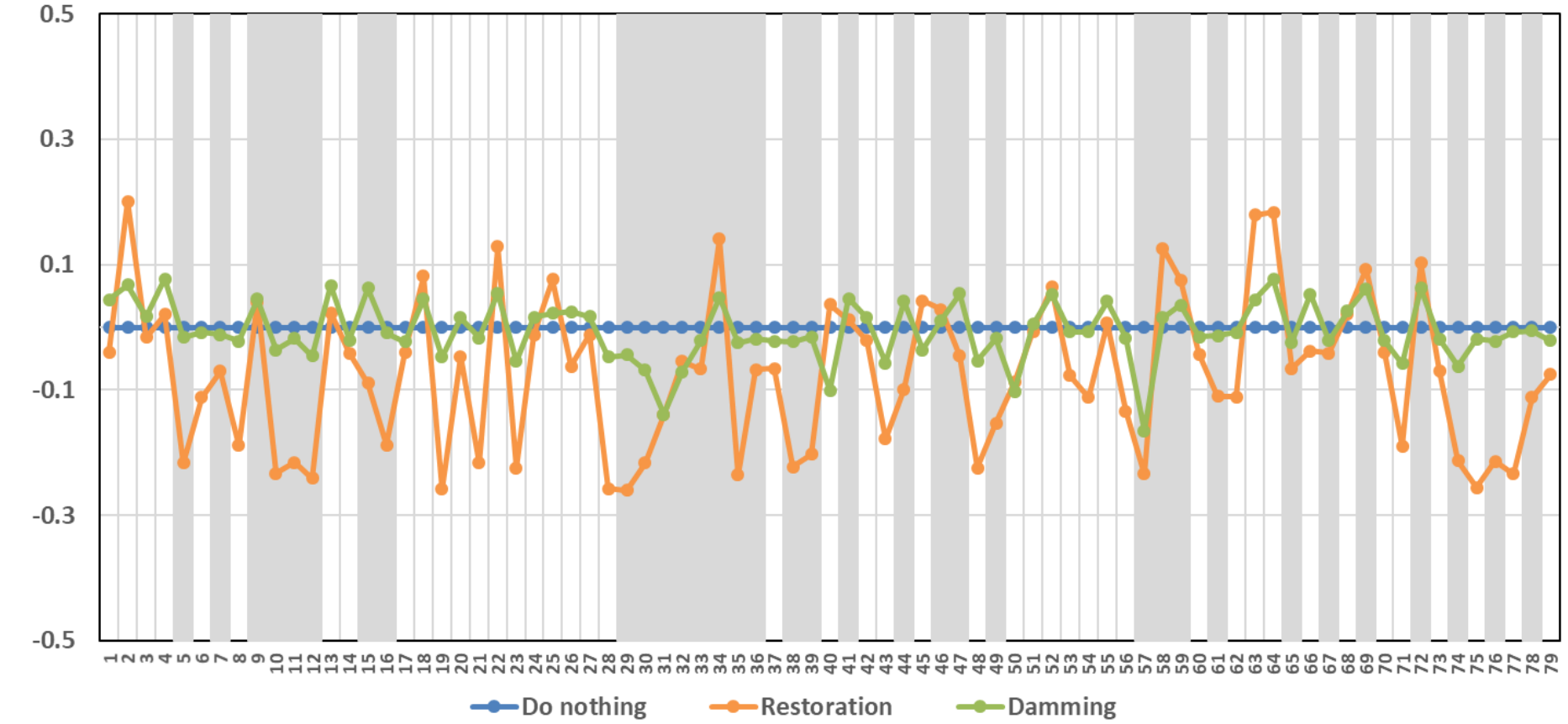
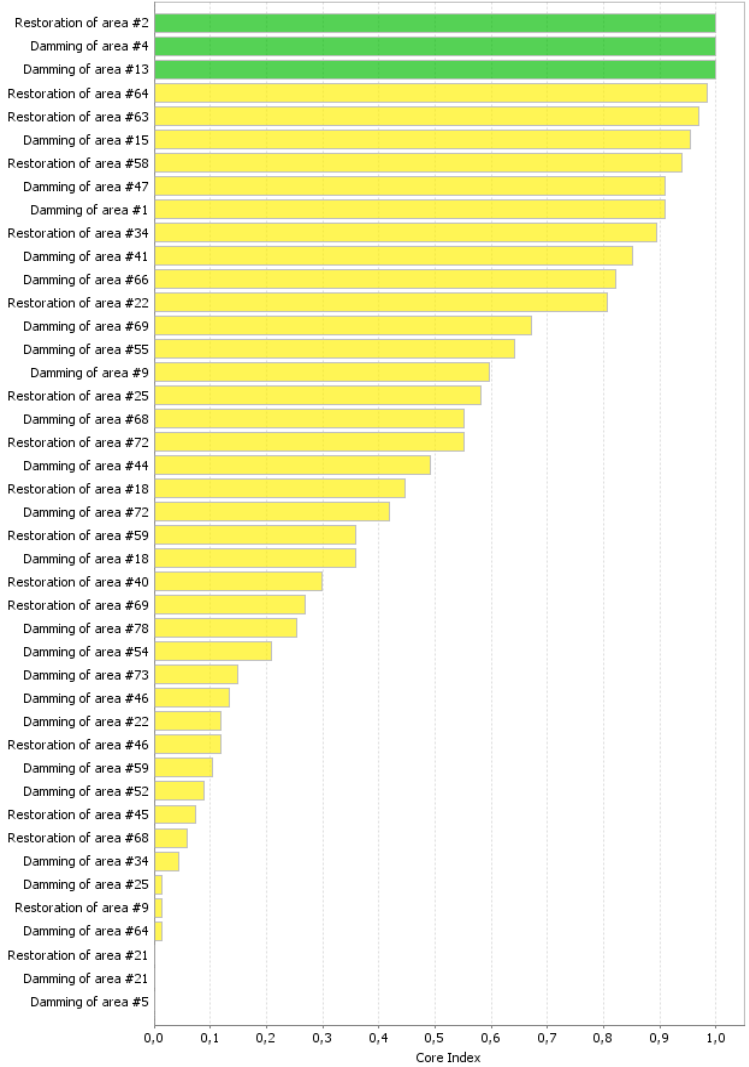
Overall values of different rewetting options for each peatland stand

- Results for each of the weight set of 13 respondents (here median weights)
- Connected stands are with the same background color

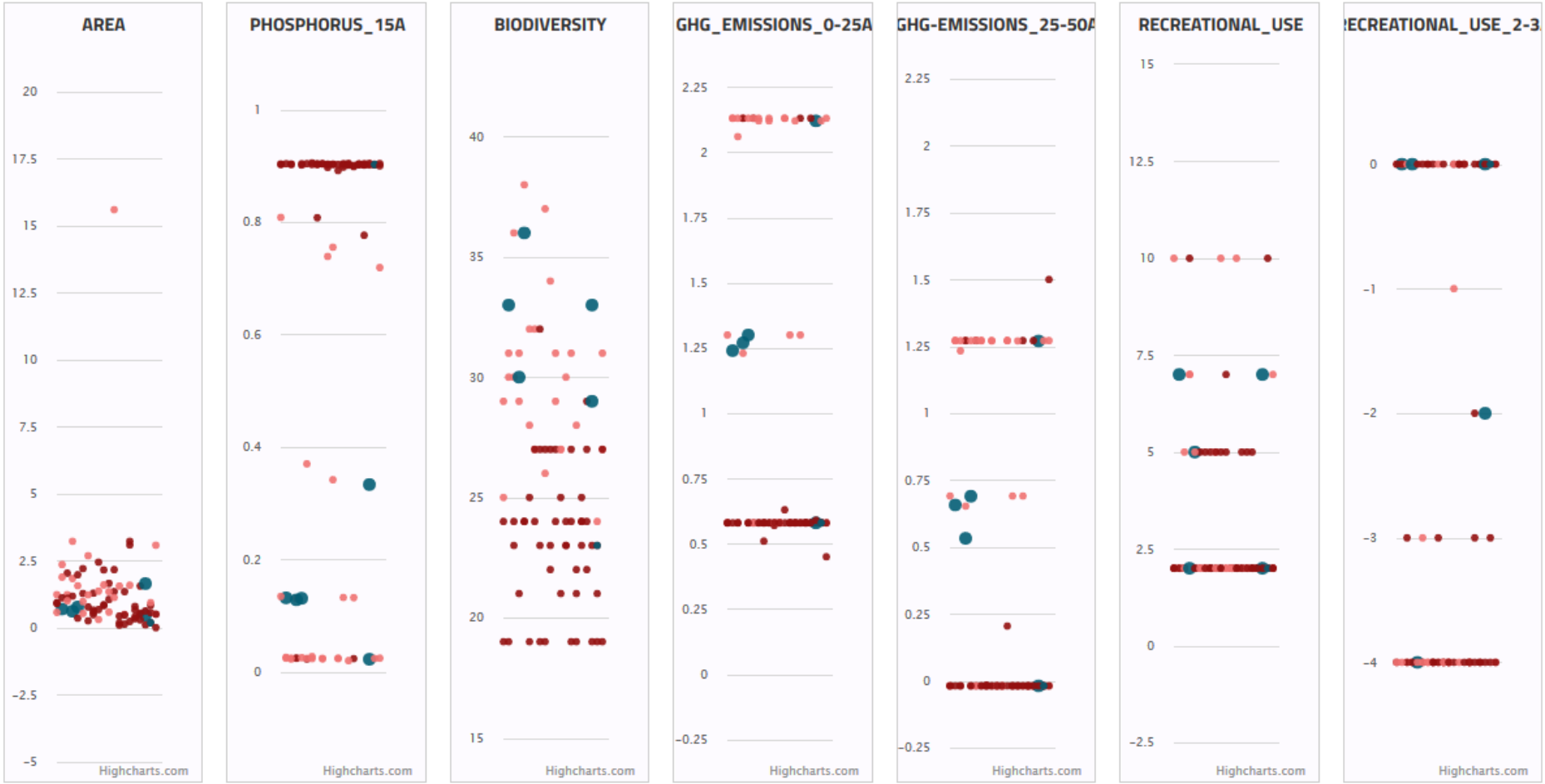


Results of RPM

- The value of a portfolio as a sum of the MAVT values of the included
  - Constraint of 25 ha at most to rewet
  - Constraints for not including both damming and restoring for the same area
- Core Index is the share of efficient portfolios that include the action
- Efficient portfolios first identified without any preference information
  - In the workshop with interactive ‘what-if’ analysis with the participants
  - Also the results based on the average criteria weights of 13 participants



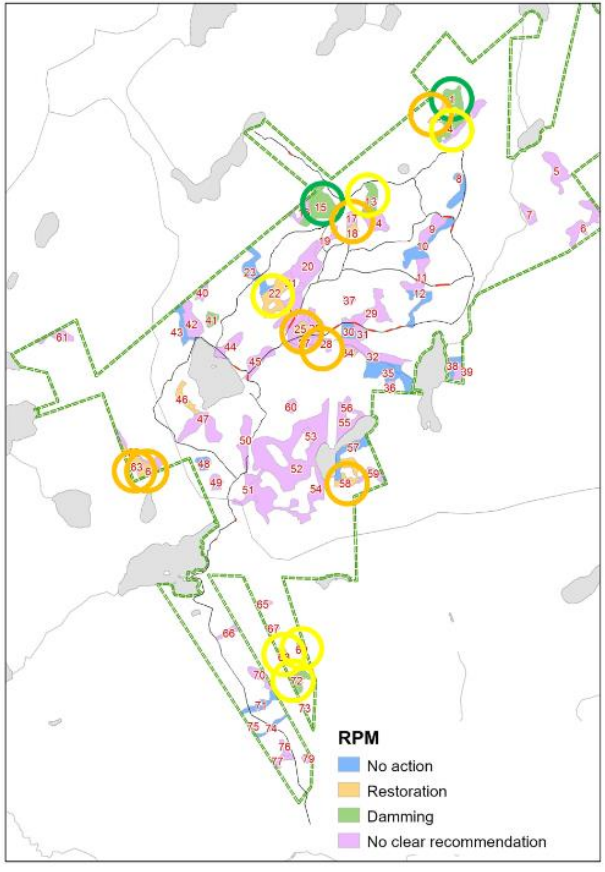
Combined solution of YODA for the rewetting based on nine participants' answers

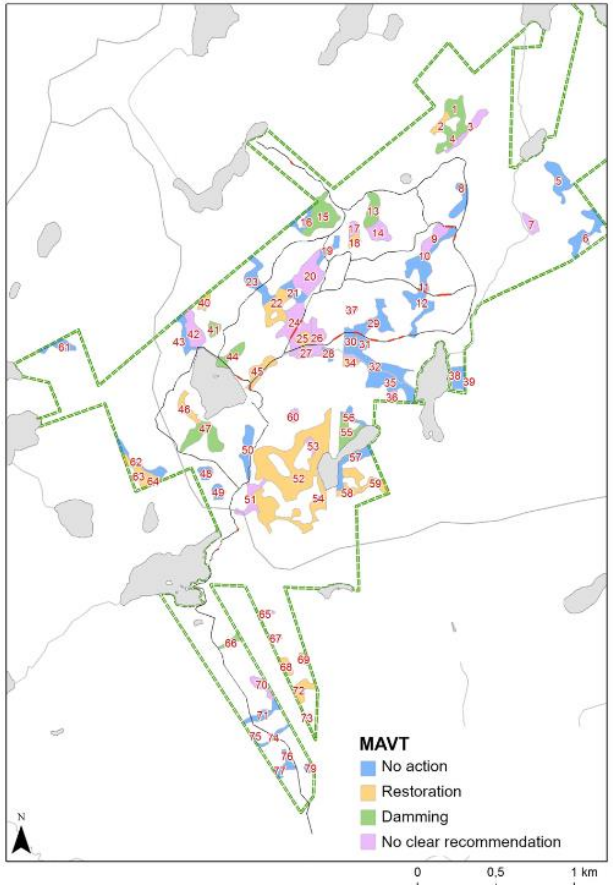


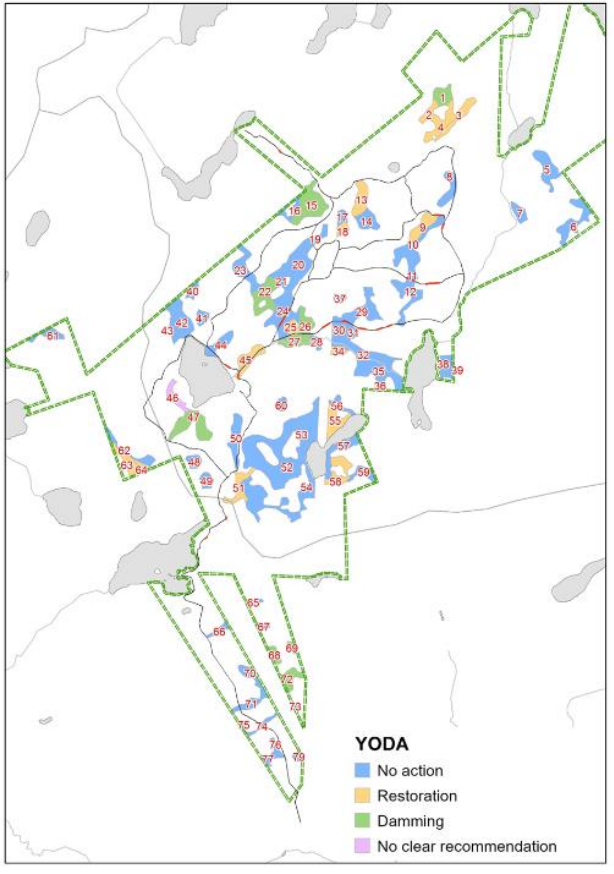
Results of all three methods presented on the map

The peatland units circled in the left figure:

All three decision support methods give
- restoration as the best option
- damming as the best option
- restoration or damming as the best option







Reflections on the results

- Most of the suggestions by the methods were similar to each other
  - 66 of 79 peatland stands with no contradictory suggestions (i.e. all the methods suggested the same action or “no clear suggestion”)
- Recommendations of the methods resonated quite well with the participants' initial ideas of good rewetting options for those areas
  - City of Tampere had already some thoughts about what peatland stand to rewet
  - The results give support for their final decision
- Maps illustrating the desirability of rewetting options were useful in understanding the situation
  - Next step to develop real-time spatial analyses on how changes in weights or acceptable thresholds affect the results of the analysis
- More research needed to take interactions between the actions into account

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Strengths of the methods

- **MAVT**
  - Ability to highlight the strengths and weakness of all three rewetting options for a single peatland stand
- **RPM**
  - Possibility to determine efficient portfolios of peatland stands within constraints, even without precise preference information
- **YODA**
  - Simplicity and possibility to apply it independently on the Internet

Picture:
A dam at
Kintulammi

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Feedback from the participants

- Methods generally helpful in addressing the rewetting options for drained peatland stands
  - Three methods received relatively similar feedback
  - MAVT and YODA slightly easier to understand than RPM
    - MAVT introduced in the first session and YODA tasks on their own laptops
- Principles of the methods difficult to capture for some people
  - Very limited time to familiarize themselves with three methods
- Most comments on the methods were positive…
  - *"The models are able to do a huge job, much bigger than a single officer ever could"*
- But also some worries…
  - *"Whatever the computer model says, I am not sure whether it would work in practice …"*

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Amount of facilitation needed to reduce the behavioral biases of participants using the method

- **MAVT**
  - Facilitation needed to reduce the possibility of behavioral biases in weighting related to e.g. ranges of criteria
- **RPM**
  - Principles of the method based on MAVT – Similar biases can apply
  - In addition, the use of the method requires profound understanding of PDA
- **YODA**
  - Elimination principle of peatland stands according to easy to understand and can be carried out by participants alone
  - Non-compensatory nature of the method may cause the portfolio to be inefficient

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Outputs and use of the results

Outputs	- MAVT: evaluation of options for each peatland stand - Excel tool tailored for the City of Tampere to help analyzing options for each peatland stand - RPM and YODA: efficient portfolio of actions if 25 hectares were rewetted
Use of the results	- The city of Tampere is yearly rewetting a few new peatland stands - The planners use actively the results and the Excel tool to support the decision making on what peatland stands to rewet next - Analysis also provides means for explaining the reasoning behind the selected options in policy making

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Case 3: Peatland conservation in southern Finland

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Case: Peatland conservation in southern Finland

Problem	- At the time of the case, peat was an important energy source in Finland
	  - Area of energy peat production was ~470 km^2 and annual energy production ~11 TWh (~9 % of domestic energy production)
	- Peat production also has adverse effects
	  - CO_2 emissions, impacts on biodiversity, waters and recreation
	- Various stakeholders
	  - Peat production companies, recreational users, nature conservationists, …
	- **Aim to analyze impacts of different strategies for conserving peatlands**

Time	2016–2018
Problem owner	Academy research project
Stakeholders/ participants	Nine representatives from three Ministries (of Employment and the Economy, of Environment and of Agriculture and Forestry), Central Union of Agricultural Producers and Forest Owners, Finnish Association for Nature Conservation, peat production company Vapo (now Neova), Outdoor Association of Finland, Bioenergy Association of Finland, and Finnish Environment Institute

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Selection of DA approach

Characteristics of the problem	- Strategic planning situation (no actual decision making involved) - Bipolarized situation - Peat production versus all the other uses of the peatlands - Studying the use of the ecosystem service concept in the case - Much time available (Academy research project)
Selected weight elicitation approach	**Decision Analysis Interviews** - Each participant was interviewed in a 2–3-hour interview - During the interview, an Excel model of the case was filled in with the interviewee's weights (with the SWING method) - The results were analyzed in collaboration with the interviewee, who was allowed to adjust the weights if needed - Also sensitivity analysis, by analyzing impacts of the weight changes to the results - Decision analyst actively asked additional weight related questions to identify possible biases

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Decision Analysis Interviews

Advantages

- More careful answers due to the presence of the analyst
- Possible misunderstandings, mistakes and biases can be detected
- Immediate feedback and iterative weight elicitation
- Enhances learning
- Improves trust and commitment to the method and results

Challenges

- Requires time and commitment from stakeholders
- Quite a laborious procedure
- Experienced decision analyst's help is needed
- The decision analyst can unintentionally influence interviewees answers

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MCDA process in the peatland restoration case

Expert work

Preliminary work within the research team including the identification and structuring of the problem and its elements

Preliminary assessment of the impacts in the research team

Preparing of the background material for the DAIs and getting comments from stakeholders by email

Analysis of the results in the research team

Stakeholder collaboration

Stakeholder workshop 1
Identification of the case and the related ecosystem services

Stakeholder workshop 2
Assessment of the impacts

Decision analysis interviews
with stakeholders

Stakeholder workshop 3
Analysis of the results and suggestions for the future

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MCDA/ecosystem service -related research questions in the peatland case

- In 2000's, ecosystem service (ES) concept introduced
  - Explicit focus on the benefits (i.e. services) of the ecosystems that can increase human well-being
- There are various classifications for ecosystem services that are usually divided into three main categories:
  1. **Provisioning services** (e.g. clean water, energy)
  2. **Regulation and maintenance services** (e.g. climate control)
  3. **Cultural services** (e.g. recreation)
  - These are further divided into more detailed classes (48 altogether)
- Hierarchical structure that is very similar to a value tree of MCDA
  - What happens if we take the ecosystem service classification as such as a basis of value tree?
  - Are the desirable properties of value tree fulfilled?

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Example of ecosystem service classification

CICES for ecosystem service mapping and assessment				
CICES for ecosystem accounting				
Section	**Division**	**Group**	**Class**	**Class type**
Provisioning	Nutrition	Biomass	Cultivated crops	Crops by amount, type
			Reared animals and their outputs	Animals, products by amount, type
			Wild plants, algae and their outputs	Plants, algae by amount, type
			Wild animals and their outputs	Animals by amount, type
			Plants and algae from in-situ aquaculture	Plants, algae by amount, type
			Animals from in-situ aquaculture	Animals by amount, type
		Water	Surface water for drinking	By amount, type
			Ground water for drinking	
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Material by amount, type, use, media (land, soil, freshwater, marine)
			Materials from plants, algae and animals for agricultural use	
			Genetic materials from all biota	
		Water	Surface water for non-drinking purposes	By amount, type and use
			Ground water for non-drinking purposes	
	Energy	Biomass-based energy sources	Plant-based resources	By amount, type, source
			Animal-based resources	
		Mechanical energy	Animal-based energy	Byamount, type, source

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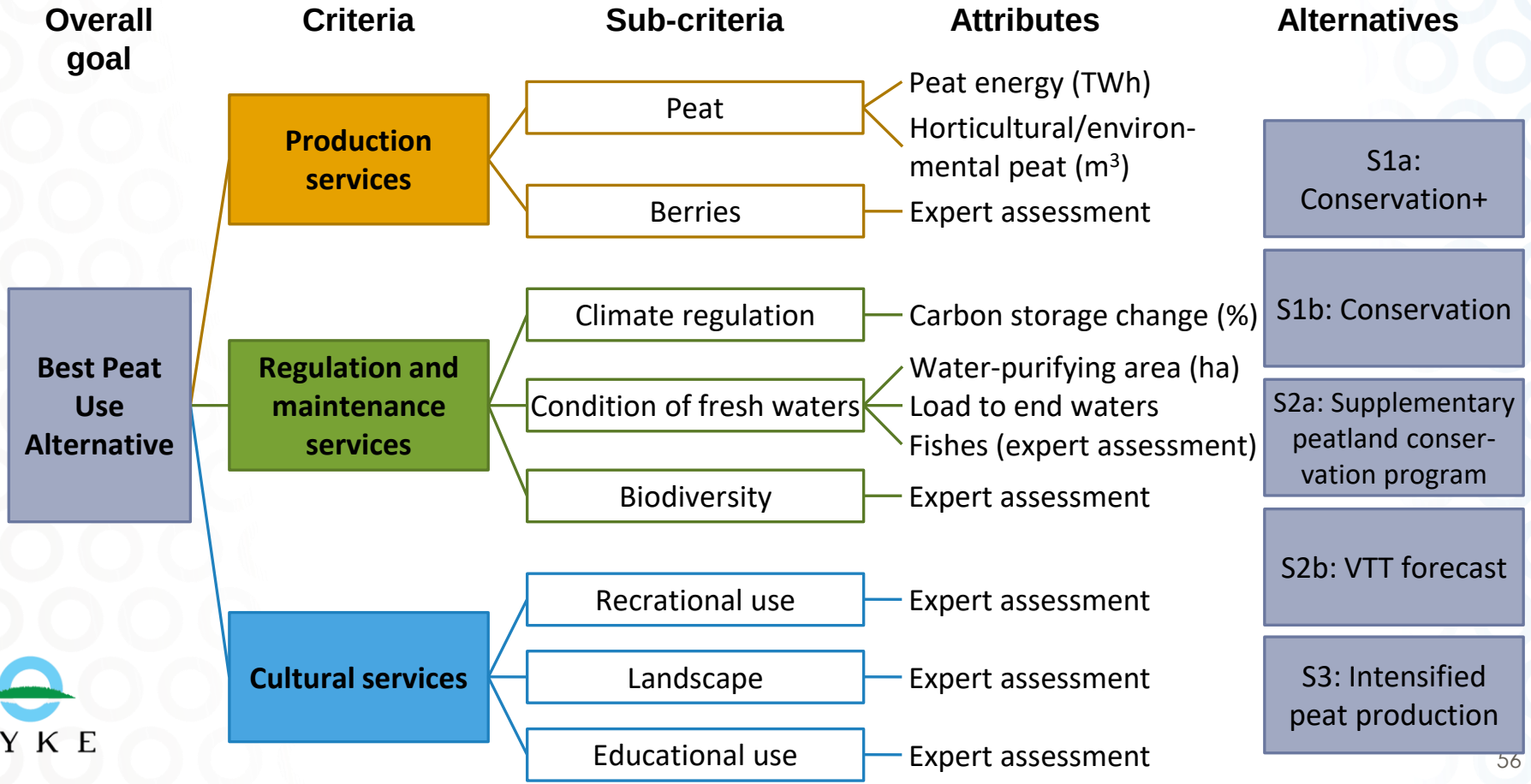
Value tree of the case



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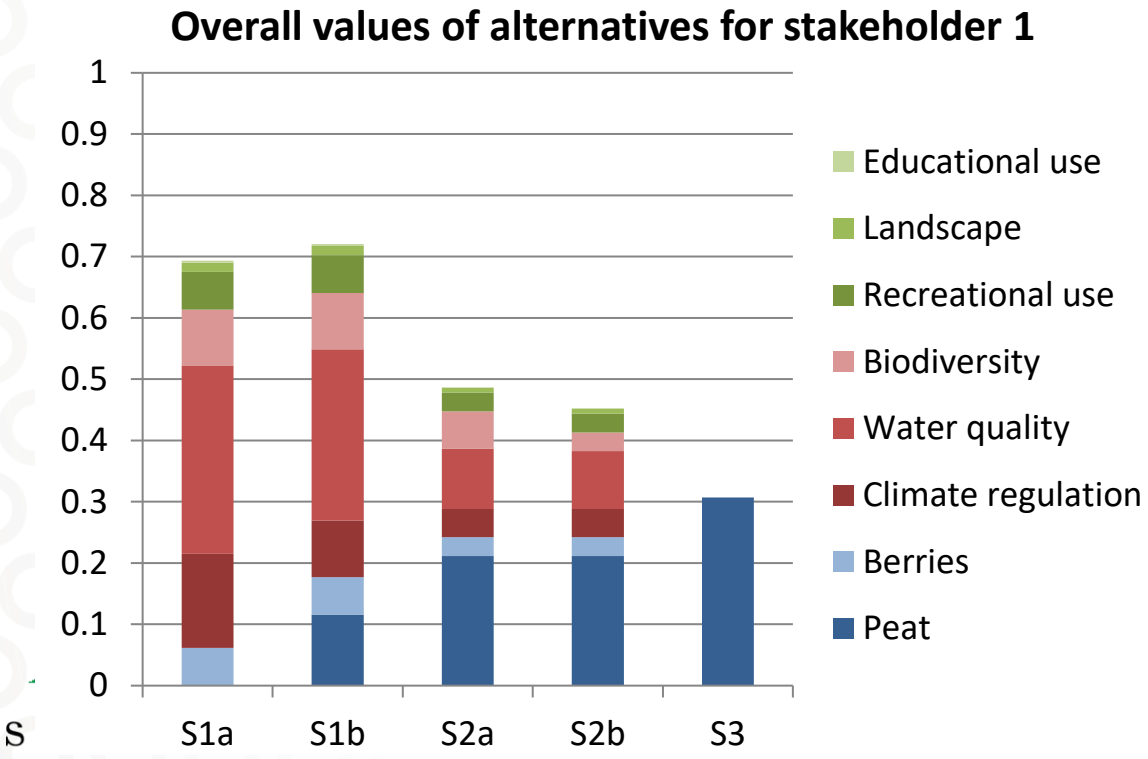
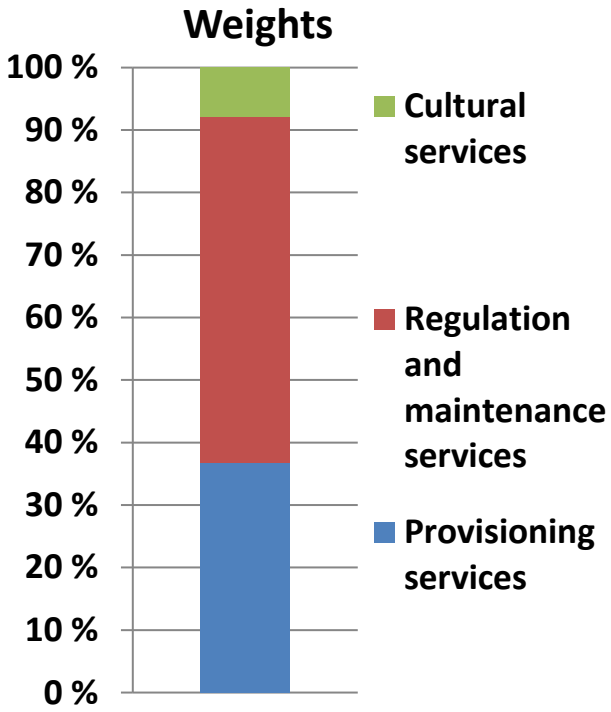
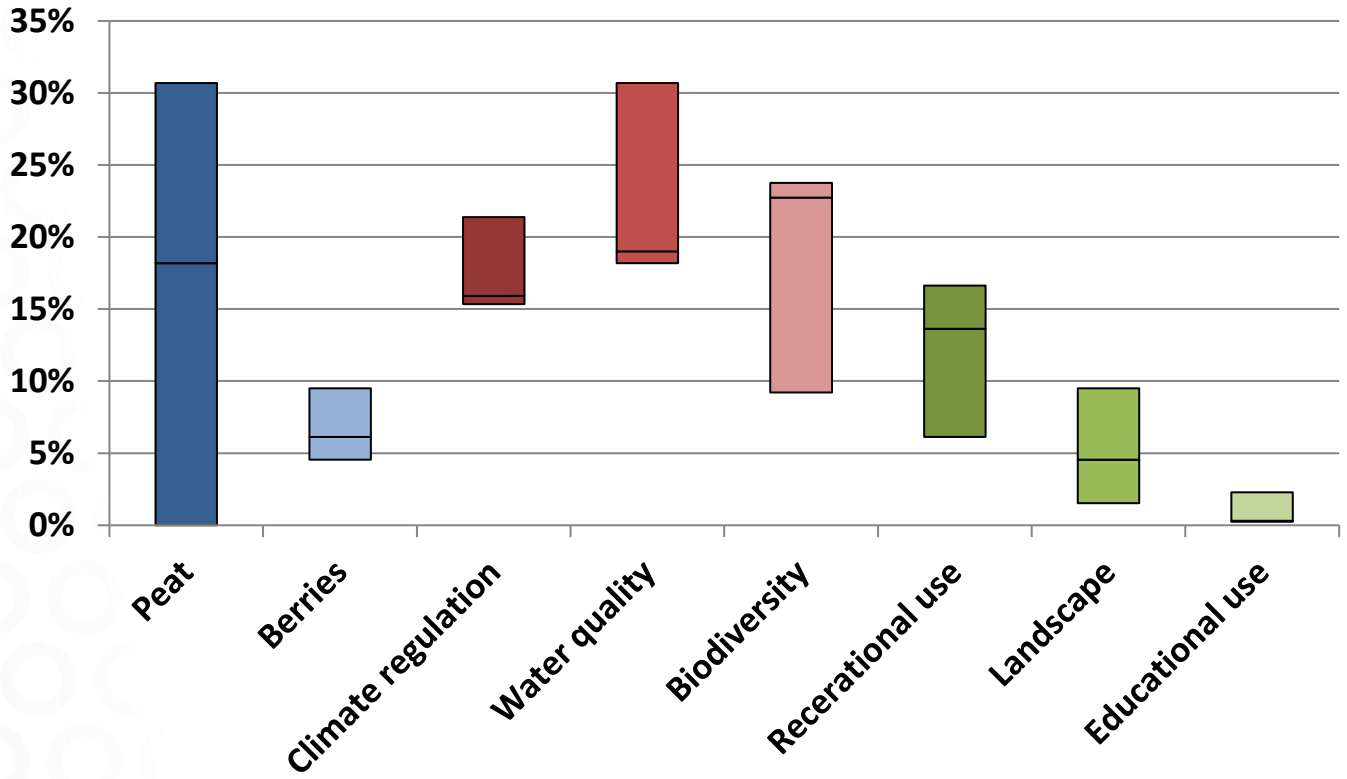
Decision analysis interviews: Example of the result of a single stakeholder





Example of the comparison of the stakeholders' preferences



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Desirable properties of the value tree

- **Balance between completeness and conciseness**
  - All the relevant objectives should be included in the value tree
  - There should not be irrelevant attributes in the value tree
    - Contradictory to the first one – one has to make trade-offs between these
- **Operationality and understandability**
  - Attributes should be understandable, meaningful and assessable
  - Possibility of the biases related to the process should be minimized
- **Decomposability and preferential independence**
  - It should be possible to analyze one attribute at time
  - Performance on one objective should not depend on performances on other objectives
- **Non-redundancy**
  - The set of attributes should be non-redundant to avoid double counting
- **Measurability**
  - The achievement of objectives should be measurable as accurately and unambiguously as possible

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How are desirable properties met in value tree based on ecosystem service classification?

- **Balance between completeness and conciseness**
  - \+ Acts as a checklist to take all the important issues into account
  - – The value tree can easily become too detailed
  - – Different aspects of classification can focus discussion on irrelevant issues
- **Operationality and understandability**
  - – The structure does not allow any room for modifications according to the needs of the case → Can decrease innovative thinking
  - – Top level sections of ecosystem services might not be very intuitive → Might be difficult to weight these in hierarchical weighting
- **Decomposability and preferential independence**
  - 0 Does not provide any help, but does not have any harm either
- **Non-redundancy**
  - – Classification itself has already quite much of double-counting
- **Measurability**
  - \+ The classification provides suggestions for how to measure different ESs

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Outputs and use of the results

Outputs	- Report and articles about the results of the impacts of various strategies for different uses of peatland - Research viewpoint: Good practices for applying the ecosystem service concept with MCDA - Identified pitfalls related to the application of ES concept in MCDA

Use of the results	- Helped to increase understanding of the various views
	  - Structured view of the ecosystem services provided by the peatlands
	  - Illustration of the pros and cons of various strategies
	  - Increased understanding the scales of the impacts of different options
	- Difficult to measure direct impacts to actual decision making
	  - Reporting of the results may have some impacts through changes in the tone of public discourse

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Lessons learned

- **Various ways and methods to carry out the MCDA process**
  - Applicability of the methods depends on the characteristics and needs of the case
- **Commitment of the stakeholders to the process increases with the level of their engagement**
  - Stakeholder participation essential to include the values of various stakeholder groups into the process
  - Trade-offs have to be often made also in the selection of the approach between the level of engagement and the availability of resources (time, costs, etc.)
- **The process itself is often be more important than numerical results**
  - MCDA provides systematic framework for gathering information and discuss issues of agreement/disagreement

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Why MCA (Multi-Criteria Analyses)?

“Y.M.C.A. – I'm sure they can help you today”

Village people, 1978

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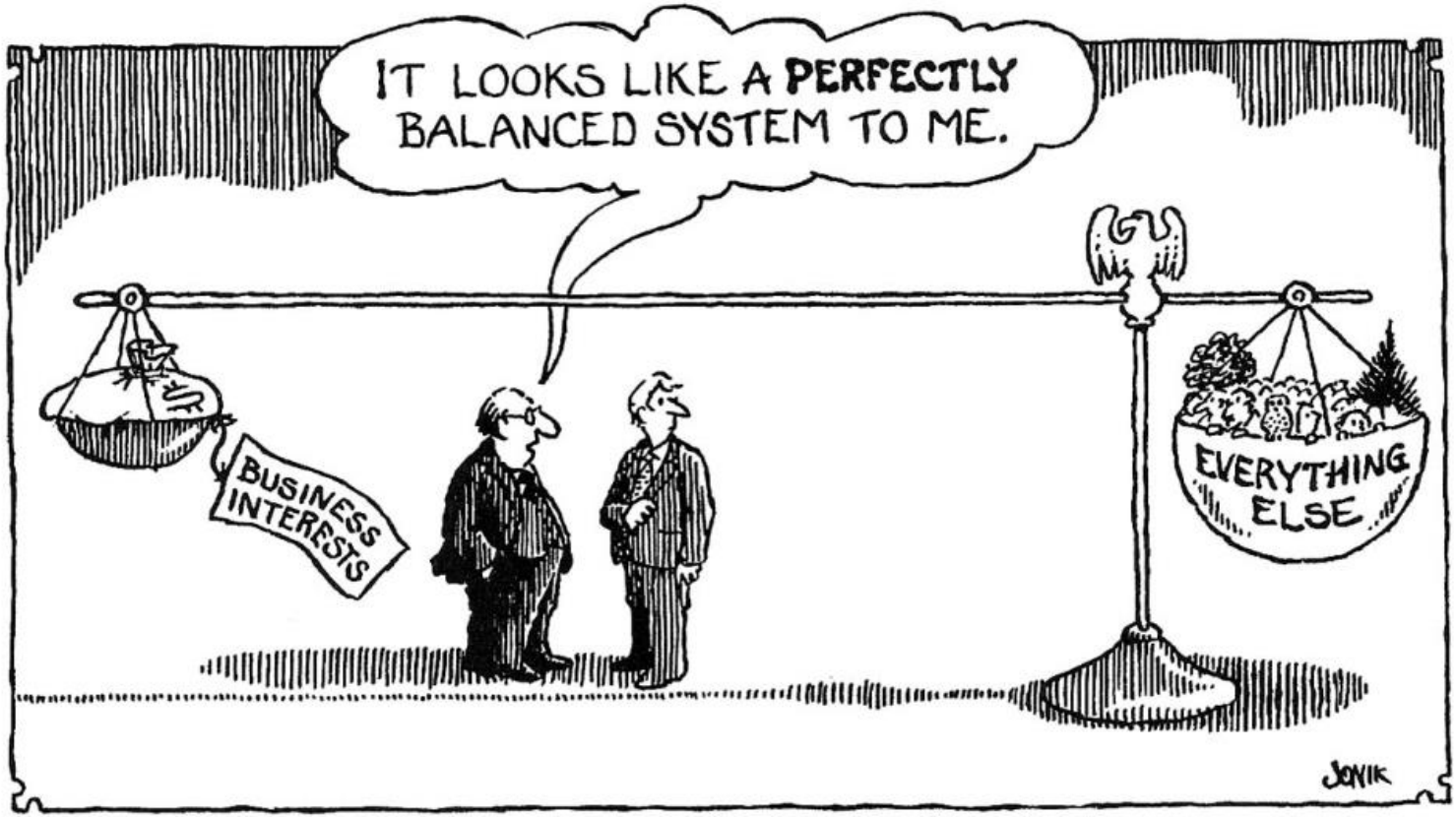
Thank you!



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