Multi-criteria decision analysis (MCDA) in ecosystem service valuation

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Introduction and 'State-of-the-art'

Multi-Criteria Decision Analysis (MCDA) is a general framework for supporting complex decision-making situations with multiple and often conflicting objectives that stakeholders groups and/or decision-makers value differently. A typical example of a decision-making situation assisted by MCDA methods is determination of an appropriate water regulation policy, which has a variety of economic, ecological and social consequences regarded as desirable by some stakeholders (e.g. downstream farmers) and undesirable by others (e.g. recreational fishermen).

MCDA is an "umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter" (Belton and Stewart, 2002, p. 2). It is rooted in operational research and support for single decision-makers (Mendoza and Martins, 2006). Recently the emphasis has shifted towards multi-stakeholder processes to structure decision alternatives and their consequences, to facilitate dialogue on the relative merits of alternative courses of action, thereby enhancing procedural quality in the decision-making process (Fish et al., 2011).

For the aim of ecosystem service assessments, MCDA methods have been seen variably as (i) an alternative to economic valuation (Vatn, 2009; Wegner and Pascual, 2011; Chan et al., 2012) (ii) a complementary approach to cost-benefit analysis, and (iii) as a decision support system that integrates economic and non-economic values (Newton et al., 2012). Related to point (i), several scholars have recommended the use of MCDA methods when addressing intangible values such as cultural and heritage values. MCDA also provides a compatible methodological framework for deliberative valuation, which is considered helpful in addressing plural value dimensions related to common goods such as ecosystem services (Vatn, 2009, Maxwell et al., 2011). MCDA methods can also incorporate information from monetary valuation studies and provide a framework for integrated valuation (e.g. Newton et al., 2012), and they are frequently used in spatial explicit land use models (Schaldach et al., 2011, Priess et al., 2011, Geneletti, 2013).

The process of MCDA

The basic idea of MCDA methods is to evaluate the performance of alternative courses of action (e.g. management or policy options) with respect to criteria that capture the key dimensions of the decision-making problem (e.g. ecological, economic and social sustainability), involving human judgment and preferences. The steps in a MCDA process are presented in Figure 1 and a worked example is available in the Extranet (WP4, Training materials, "MCDA_an example").

MCDA methods are **integrative evaluation methods** in the sense that they combine information about the performance of the alternatives with respect to the criteria (scoring) with subjective judgements about the *relative* importance of the evaluation criteria in the particular decision-making context (weighting). Multi-Attribute Value Theory based MCDA methods further require subjective judgement about the normalisation/scaling of impacts. In MCDA literature it is often assumed that the performance scores are determined on the basis of objective expert evaluation, while the relative importance of the criteria, the weighs, are derived from subjective value judgments by decision-makers and/or participants. However, also expert opinions can be disputed in conflicting environmental management situations, and therefore it is important to engage the participants also in the impact assessment stage and not only in the weighing stage (Saarikoski et al., 2013). All MCDA methods follow the basic steps illustrated in Figure 1, but they may

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use different methods for preference elicitation. The two MCDA methods that are used in OpenNESS are Multi-Attribute Value Theory and Rank-Based methods. For a detailed analysis of pros and cons of various MCDA methods in different appraisal contexts, see de Montis et al. (2005).

In the **Multi-Attribute Value Theory** (MAVT) approach, participants are asked to assign numerical weightings to reflect the relative importance of each appraisal criterion (e.g. allocating 100 'importance points' across the various criteria using a cardinal scale[2]). It should be noted that the weightings reflect how much participants care about the *differences* in performance of alternatives under each criterion. An example of software that is based on MAVT, and supported by OpenNESS project, is Web-HIPRE (Mustajoki and Hämäläinen, 2000).

Rank-based methods differ from MAVT in that they use ordinal scale[3] instead of cardinal scale and ask participant to provide a rank order of the criterion (What is the most important criterion for you, second most important, etc.) This approach requires less cognitive effort from the participants but it also loses some information about the relative importance of the criteria. An example of software, which is based on raking of options on an ordinal scale, and supported by OpenNESS project, is AURORA (de Keyser and Springael, 2009).

Advantages and disadvantages of MCDA methods in ecosystem service valuation

Advantages of MCDA include:

- It can structure an assessment of a complex problem along both cognitive and normative dimensions, both of which are essential in evaluating ecosystem services (Vatn, 2009).
- It allows comparison of ecological objectives with socio-cultural and economic ones in a structured and shared framework (Mendoza and Martins, 2006)
- It can facilitate multi-stakeholder processes, transparency and discussion about the subjective elements in policy analysis, including the nature and scope of the decision problem, the selection and definition of options (alternatives), and the characterization and prioritization of evaluation criteria (Stirling, 2006, Keune and Dendoncker, 2013).
- It can deal with incomplete and uncertain information which is characteristic of most environmental planning situations by allowing use of a mixed set of both quantitative and qualitative information (Locatelli et al., 2008, Chan et al., 2012).

However, as Stirling (2006) has pointed out, MCDA has the capacity both to open up and close down environmental policy discourses. Opening up policy discourses means that all key assumptions in the analysis such as characterization of alternatives, criteria and weightings are made visible and subject to public discussion while closing down refers to an opaque process in which experts deliver a single 'optimal' policy recommendation, and the role of general public is only to state their values e.g. through WTP surveys.

Another problem with MCDA methods is that they are suited for eliciting the preferences of a relatively small group of decision makers and stakeholders, not capturing individual preferences across the whole population. Due to this lack of representativeness, Hanley (2001, p. 113) has argued that "decisions made with the aid of MCDA may well fail on the ground of representativeness and democracy". Furthermore, MCDA methods can also be used for legitimizing pre-defined decisions if they are used in a non-transparent way (Stirling, 2006).

In some situations of conflicting interests, certain attributes and alternatives promoting those attributes – such as specific ecosystem services – are categorically preferred over others, independent of the decision context. In such situations MCDA methods based on Multi-Attribute Value Theory may not be appropriate because they frame decisions as trade-offs between characteristics of alternatives. Examples of aspects people may refuse to trade-off can include cultural services and values such as spirituality or cultural identity (Chan et al. 2012) or ES that are vital for subsistence (Kenter et al., 2011). While MCDA can deal with non-commensurability in the monetary sense, it is not well-suited for dealing with what we could call

[2] Cardinal or ratio scale allows for estimation of the strength of preference or ratio between items, like twice as big.
[3] Ordinal scale allows for rank order of alternatives (1st, 2nd, etc.)

categorical non-commensurability (lexicographic preferences in the valuation literature). However, outranking methods such as NAIADE (Munda, 2004) allows adjusting for the level of compensability of certain criteria. For example, a threshold for a minimum amount of drinking-water supply could be set which is excluded from trade-off with other ES.

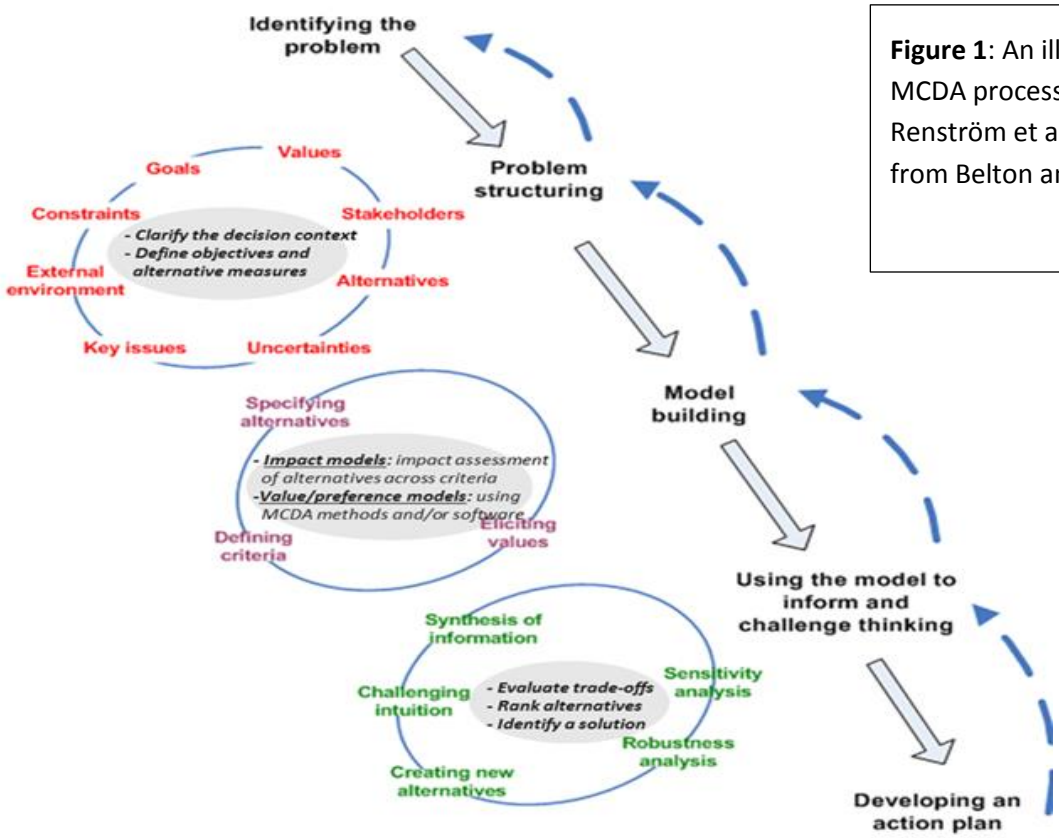

Figure 1: An illustration of a MCDA process in Catrinu-Renström et al. (2013), modified from Belton and Stewart (2002).

Problems / Issues to be discussed

1. How should MCDA process be designed for "integrated valuation" (D4.2., Braat et al., 2015)? What are the appropriate ways to integrate MCDA in different management and policy making situations, and how can they be used to address power relations and stakeholder inclusion? (see Langemeyer et al., 2016).
2. How and at which stages to involve stakeholders in MCDA processes and use group deliberation techniques in value elicitation MCDA to help people to form and articulate preferences through dialogue with others? (see Marttunen et al., 2015).
3. What are the pros and cons of different MCDA methods?
4. How to deal with ignorance, uncertainty and ambiguity dealt in different MCDA frameworks? To what extent can Bayesian Belief Networks solve challenges of assessing uncertainty in MCDA?
5. How to include external (final and intermediate) communication in the procedure, about the outcomes of the MCDA, but also about other crucial steps in the process?

Significance to OpenNESS and specific Work Packages[4]

WP1 **(Key challenges and conceptual frameworks):** The cascade model and CICES can be used to identify ES and benefits, which can be used as criteria in MCDA, while ecosystem service values may be operationalised as weights (see Langemeyer et al., 2016).

[4] For a brief description of the OpenNESS Work Packages see: http://openness-project.eu/about/work-packages

WP2 **(Regulatory frameworks and drivers of change):** Analyse the institutional conditions for operational application of the different valuation methods, including MCDA, and the outcomes of these analyses. How are ecosystem service values considered in real-world decision-making and how can valuation methods better relate to it?

WP3 **(Biophysical control of ecosystem services):** The use of MCDA methods requires that we can measure or estimate the performance of the alternatives with respect to evaluation criteria. WP3 methods can be used for quantifying the supply of ES in various management scenarios or policy options.

WP4 **(Valuation of the demand for ecosystem services):** Non-monetary scaling and weighting methods for preference elicitation in MCDA methods will be investigated as alternative to economic valuation methods in ecosystem service valuation context.

WP5 **(Place-based exploration of ES and NC concepts):** Different MCDA methods are being or will be tested in several OpenNESS case studies

WP6 **(Integration: Synthesis and Menu of Multiscale Solutions):** The examples of MCDA application in OpenNESS case studies as well as methodological guidance will be part of the Menu of Multi-Scale Solutions in the Common Platform.

Relationship to four challenges[5]

Human well-being: MCDA methods provide a pluralistic approach to evaluating the various aspects of human well-being pertaining to urban planning, water management and land use decisions. It can also be used for evaluating well-being aspects of decisions in trade (e.g. in medicinal plants or in animal products), monetary policy (e.g. carbon taxes, agricultural subsidies), and development (e.g. REDD schemes).	**Sustainable Ecosystem Management:** MCDA methods can help in finding sustainable ecosystem management strategies and policies, including sustainable use of ecosystem services according to combined ecological, social and ecological criteria. It can also be used in ex-post and ex-ante evaluation of wider social and economic choices following from a specific SEM (or other environmental) strategy or policy
Governance: MCDA methods can promote good governance by facilitating open discussion about the impacts of alternative courses of actions as well as distributional impacts.	**Competiveness:** MCDA methods can also address the economic impacts and competitiveness of alternative ecosystem service management strategies.

Recommendations to the OpenNESS consortium:

We suggest testing MCDA methods in the case studies, when applicable, and do that in a participatory fashion as outlined in this SP.

Suggested three "must read" papers

Marttunen, M. & Hämäläinen, R. (2008): The Decision Analysis Interview Approach in the Collaborative Management of a Large Regulated Water Course. *Environmental Management* **42**: 1026-1042.

Stirling, A. (2006): Analysis, participation and power. Justification and closure in participatory multi-criteria analysis. *Land Use Policy* **23**: 95-107.

Geneletti, D. (2013): Assessing the impact of alternative land-use zoning policies on future ecosystem services. *Environmental Impact Assessment Review* **40**: 25-25.

5 There are certainly more societal challenges; the reduced number presented here is due to the four major challenges mentioned in the work programme of FP7 to which OpenNESS responded.

Further Cited papers or Background papers:

Braat, L. C. , E. Gómez-Baggethun, B. Martín-López, D. N. Barton, M. García-Llorente, E. Kelemen, H. Saarikoski (2014): Framework for integration of valuation methods to assess ecosystem service policies. EU FP7 OpenNESS Project Deliverable 4.2. European Commission FP7. Grant Agreement no. 308428.

Catrinu-Renström, M.D. et al. (2013): *Multi-criteria analysis applied to environmental impacts of hydropower and water resources regulation projects.* Sintef Report TR A7339.

Chan, K.M.A. et al. (2012): Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics* **74**: 8-18.

de Keyser, W. and J. Springael (2009): Why don't we KISS!? A contribution to close the gap between real-world decision makers and theoretical decision-model builders. Brussels, University Press Antwerp, http://hdl.handle.net/10067/798470151162165141.

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Hanley, N. (2001): Cost-benefit analysis and environmental policy-making. *Environment and Planning C* **19**: 103-118.

Kenter, J. et al. (2011): The importance of deliberation in valuing ecosystem services in developing countries—evidence from the Solomon Islands. *Global Environmental Change* **21(2)**: 505–521.

Keune, H. and N. Dendoncker (2013): Negotiated complexity in ecosystem services science and policy making - Ecosystem Services. In: Jacobs S., Dendoncker N. and H. Keune (eds.) Ecosystem Services – Global Issues Local Practices, Elsevier, New York, p. 167-180, http://www.sciencedirect.com/ science/article/pii/ B9780124199644000159

Langemeyer, J., Gómez-Baggethun, E., Haase, D., Scheuer, S., & T. Elmqvist (2016): Bridging the gap between ecosystem service assessments and land-use planning through Multi-Criteria Decision Analysis (MCDA). *Environmental Science & Policy* **62**: 45-56.

Locatelli, B., Rojas, V., and Z. Salinas (2008): Impacts of payments for environmental services on local development in northern Costa Rica: A fuzzy multi-criteria analysis. *Forest Policy and Economics* **10(5)**: 275-285.

Marttunen M., Mustajoki J., Dufva M. and T.P. Karjalainen (2015): How to design and realize participation of stakeholders in MCDA processes? A framework for selecting an appropriate approach. *EURO Journal on Decision Processes* **3(1)**: 187–214.

Maxwell, S., et al. (2011): Social Impacts and Wellbeing : multi-criteria analysis techniques for integrating non-monetary evidence in valuation and appraisal - A discussion of current approaches and opportunities. Defra Evidence and Analysis Series, Paper 5.

Mendoza, G.A. and H. Martins (2006): Multi-criteria decision analysis in natural resource management: A critical review of methods and new modeling paradigms. *Forest Ecology and Management* **230**: 1-22.

Munda, G. (2004): Social multi-criteria evaluation: Methodological foundations and operational consequences. *European Journal of Operational Research* **158(3)**: 662–677.

Mustajoki, J. and R.P. Hämäläinen (2000): Web-HIPRE: Global decision support by value tree and AHP analysis. *INFOR* **38(3)**: 208-220.

Newton, A. C., Hodder, K., Cantarello, et al. (2012). Cost-benefit analysis of ecological networks assessed through spatial analysis of ecosystem services. *Journal of Applied Ecology* **49(3)**: 571-580.

Spangenberg, J. and J. Settele (2010): Precisely incorrect? Monetising the value of ecosystem services. *Ecological Complexity* **7**: 327–337.

Priess J. A., et al. (2011): The consequences of land-use change and water demands in Central Mongolia. *J. Land Use Policy* **28(1)**: 4-10

Wegner, G. and U. Pascual (2011): Cost-benefit analysis in the context of ecosystem services for human well-being: a multidisciplinary critique. *Global Environmental Change* **21**: 492-504.

Saarikoski, H., Mustajoki, J. and M. Marttunen (2013): Participatory multi-criteria assessment as 'opening up' vs. 'closing down' of policy discourses: a case of old-growth forest conflict in Finnish Upper Lapland. *Land Use Policy* **32**: 329-336.

Schaldach R., et al. (2011): An integrated approach to modelling land-use change on continental and global scales. *Environmental Modelling & Software* **26(8)**, 1041-1051.

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