Supplementary Appendix to the publication: Marcot, B. G., M. P. Thompson, M. C. Runge, F. R. Thompson, S. McNulty, D. Cleaves, M. Tomosy, L. Fisher, and A. Bliss. 2012. Recent advances in applying decision science to managing national forests. Forest Ecology and Management 285:123-132.

Supplementary Appendix. Tools and approaches useful in stages of structured decision-making, with examples of applications. Many tools or approaches can serve more than one stage. Areas of uncertainty addressed by each tool or approach (sensu Ascough et al. 2008): LU = linguistic uncertainty, KU = knowledge uncertainty, VU = variability uncertainty, DU = decision or preference uncertainty.

Name of tool or approach	Use and type of uncertainty addressed	Examples of application
	Problem Structuring Stage	
Cognitive Mapping and Modeling	Organizes and synthesizes system components and dynamics. LU, KU	Mendoza and Prabhu, 2005 (participatory modeling and sustainable forest management); Wolfslehner and Vacik, 2011 (forest management sustainability evaluation)
Influence diagrams	Represents key system parameters, decision points, and outcomes in a qualitative graph. Can be further developed into other quantitative model types (e.g., state and transition models, Bayesian network). LU, KU	Bashari et al., 2009 (rangeland management)
Decision tree	Diagrams choices, outcomes (utilities), and probabilities to evaluate expected values of alternatives; evaluates knowledge and preference (risk attitude) uncertainties; useful for all SDM stages. KU, VU, DU	Failing et al., 2004 (adaptive management); Wan et al., 2009 (vegetation modeling)
Objectives hierarchy analysis	Helps resolve conflicting objectives, social values, and preferences. VU, DU	Maguire et al., 2004 (invasive species management)
	Problem Analysis Stage	
Simulation modeling	A broad set of tools useful for modeling system dynamics and response to management, e.g. timber growth and yield, wildfire, hydrology, climate change, weather. VU, DU	Krawchuk and Cumming, 2011 (forest fire under climate change); Vuilleumier et al., 2011 (invasive species control)
Bayesian networks	Models the conditional dependence between variables accounting for prior knowledge. KU, VU	Aalders, 2008 (land-use decisions); Dlamini, 2010 (fire risk analysis),

Name of tool or approach	Use and type of uncertainty addressed	Examples of application
Data mining	Analyzes relationships between numerous data fields in an existing database, gaining new knowledge. KU	Dlamini, 2011 (vegetation mapping)
Fuzzy logic, fuzzy set theory models	Allows computation of vague and uncertain data using a membership function for data inputs. LU, KU, VU	Glenz et al., 2008 (flooding impact on woody species growth); Reeves et al., 2006 (evaluating watershed condition and aquatic habitat)
Rough set theory	Unknown values for data are represented by their approximated lower and upper bound. KU, VU	Xie et al., 2011 (land cover data retrieval)
Analytic Hierarchy Process (AHP)	Hybrid approach allowing for imprecise and vague definitions embedded within a hierarchy. Allows for joint consideration of objective and subjective information with expert judgment. KU, VU	Coulter et al., 2006 (forest roads); Hessburg et al., 2007 (wildfire danger, fuels treatments),
Analytic Network Process (ANP)	Better for expert judgment use and capturing feedbacks and interdependencies, relative to AHP. KU, VU	Bottero et al., 2011 (wastewater treatment assessment); Wolfslehner et al., 2005 (sustainable forest management)
Rule and network induction	Results in rules or networks based on the relationship between a given set of attributes; networks can then be further developed as probability transition models or Bayesian networks. LU, KU, VU	Berger, 2004 (crop suitability)
Neural networks	Allows modeling of nonlinear and unknown relationships. KU, VU	Ejrnaes et al., 2002 (habitat quality); Scrinzi et al., 2007 (forest distribution data)
Reliability analysis	Assessment of the potential failures (probabilities and timing) of a system and their effects. VU	Chowdhury et al., 2009 (drinking water contaminants)
Scenario analysis	Considers multiple outcomes providing a range of alternatives and their likelihoods. KU	Bohnet et al., 2011 (sustainable landscape development)
Comparative risk assessment	Extends traditional risk assessment to include decision space available to managers and stakeholders to allow them to explore tradeoffs between alternative courses of action. VU, KU	Ager et al., 2007 (fuel treatment strategies); Calkin et al., 2011 (wildland fire management)

Name of tool or approach	Use and type of uncertainty addressed	Examples of application
Decision Point Stage		
Valuation & Cost-Benefit Analysis	A family of stated and revealed preference models for establishing the value of non-marketable goods and services. VU, DU	Champ et al., 2010 (hedonic pricing model and homebuyer wildfire risk perceptions); Holmes et al., 2004 (contingent valuation and riparian restoration),
Exact Optimization Methods	A variety of mathematical techniques that can identify a set of non-dominated alternatives or a single best answer. Includes linear programming, nonlinear programming, integer programming, others. VU, DU	Thompson et al., 2010 (forest road erosion control); Toth et al., 2009 (spatial harvest scheduling with habitat objectives)
Heuristic Optimization Methods	Iteratively update solution(s) through process of information exchange, self-adaptation, and competition; entails perturbing decision vector, accepting and retain new solution(s) according to various criteria. Includes evolutionary algorithms, genetic algorithms, simulated annealing, tabu search, others. VU, DU	Icaga, 2005 (water quality monitoring); Kennedy et al., 2008 (fuel treatment planning),
Multi-attribute utility theory (MAUT)	Defines a cardinal utility function according to all criteria, typically by defining performance of each. VU, DU	Merkhofer et al., 1997 (siting hazardous waste management facility); Moffett et al., 2005 (conservation planning)
Analytic Hierarchy Process (AHP)	Pairwise comparisons of attributes/criteria based on linguistic scale then converted to ratio-scale weights, which can be aggregated up through an objective hierarchy. LU, VU, DU	Darin et al., 2010 (invasive plant management); Wolfslehner et al., 2005 (sustainable forest management)
Simple Multi-Attribute Ranking Technique (SMART)	Assigns criteria weights on 0-100 scale, by scaling weights for all attributes relative to the most important attribute, assigned 100. DU	Kajanus et al., 2004 (tourism management and sustainable development); Reynolds, 2001 (salmon habitat restoration)

Stochastic Multicriteria Acceptability Analysis (SMAA)	Family of methods designed to facilitate decision-making in contexts where both criteria and preferences may be subject to uncertainty; based on exploring the weight space in order to describe the preferences that would make each alternative the most preferred one, or that would give a certain rank for a specific alternative. VU, DU	Kangas et al., 2003 (forest management plan development); Kangas et al., 2005 (natural resource management)
Implementation and Monitoring Stage		
Multimodel analysis	Multiple models for evaluating various representations of expert knowledge, scales, and variable interactions. KU, VU	Rehme et al., 2011 (general application)
Multi-agent systems	Models multiple interacting "agents" (programs, humans, or human teams), representing diverse interests, in role-playing scenarios. VU	Lynam et al., 2002 (rangeland management)

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