Characterizing Assets, Threats and Solvability with Bayesian Networks to Support Spatial Prioritization for Environmental Management

United States Environmental Protection Agency

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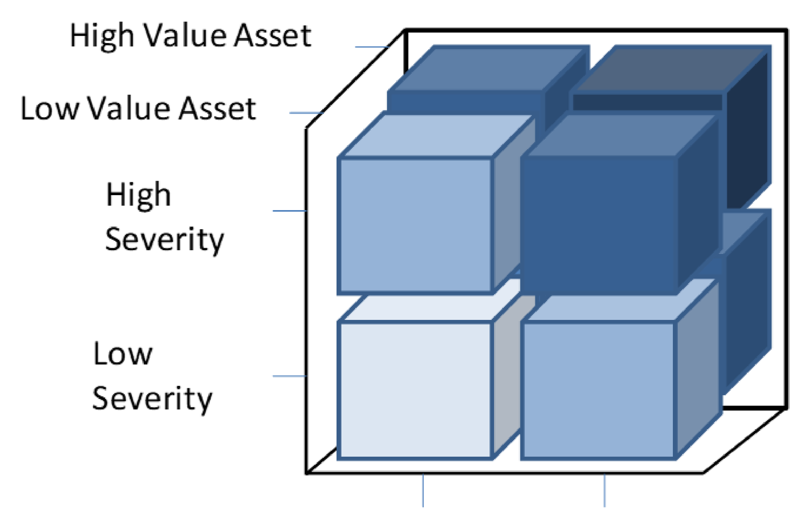
ATS (Assets, Threats, Solvability) framework



From Hajkowicz and McDonald, 2006

The Assets, Threats, and Solvability framework organizes and weights the information needed for ranking management priorities (Hajkowicz and McDonald 2006). The ATS favors options which target high value assets, threats of high severity and are highly solvable by the decisions under consideration. For environmental conservation priorities, the ATS follows the principle that costly interventions protecting habitats that are highly valued but have low threats is less desirable than less costly interventions protecting habitats with high value and high threats (Agardy et al. 2011).

Past examples of the ATS include national environmental funding (Hajkowicz and McDonald 2006) and prioritization of sub-watershed pollutants for managing coastal stressors (Barson et al. 2014). However, past applications have not included uncertainty. Assessing uncertainty with spatial alternatives in an ATS framework would be beneficial for setting environmental management priorities.

The ATS uses multicriteria decision analysis (MCDA) for integrating and weighing information from diverse sources needed for a prioritization decision (Pang et al. 2017). Below we walk through the steps of building an ATS model up to implementation with an example of watershed prioritization for coral reef protection (e.g., Cotsell et al. 2009) adapting Bayesian network approaches for MCDA (Barton et al. 2020).

ATS framework steps

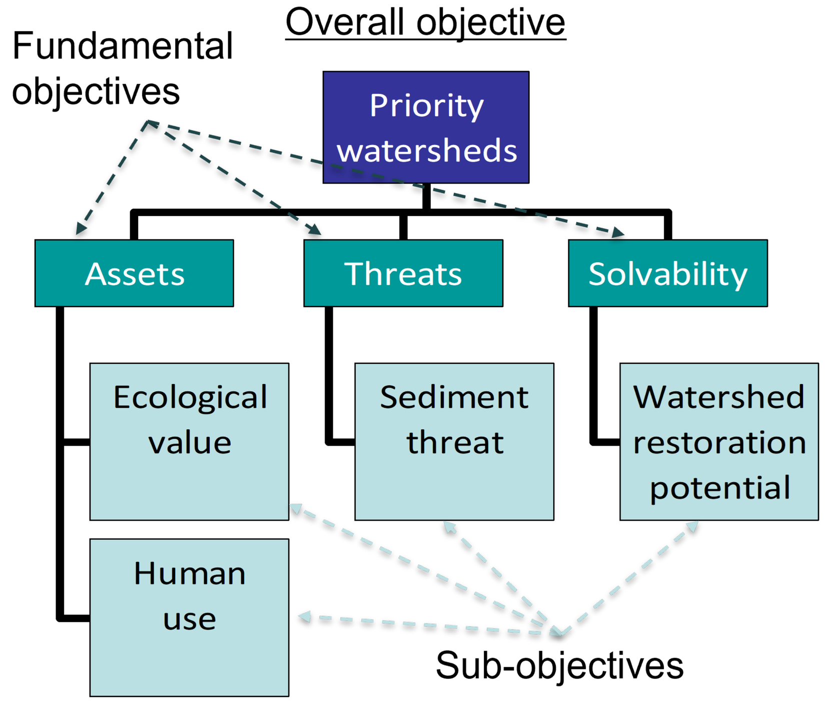
1 Construct ATS hierarchy

Start with an **overall objective** at the top of the hierarchy, In this example, it is determining the priority watersheds for restoration. The **fundamental objectives** follow the overall objective and are the ATS.

Define ATS components with **subobjectives**. Assets are ecological value and the human uses provided by the reefs adjacent to the watershed. Threats are sediment threat from the watershed. Solvability is based on the watershed restoration potential.

Define **spatial measures** for each sub-objective. These are the criteria demonstrated in the network.

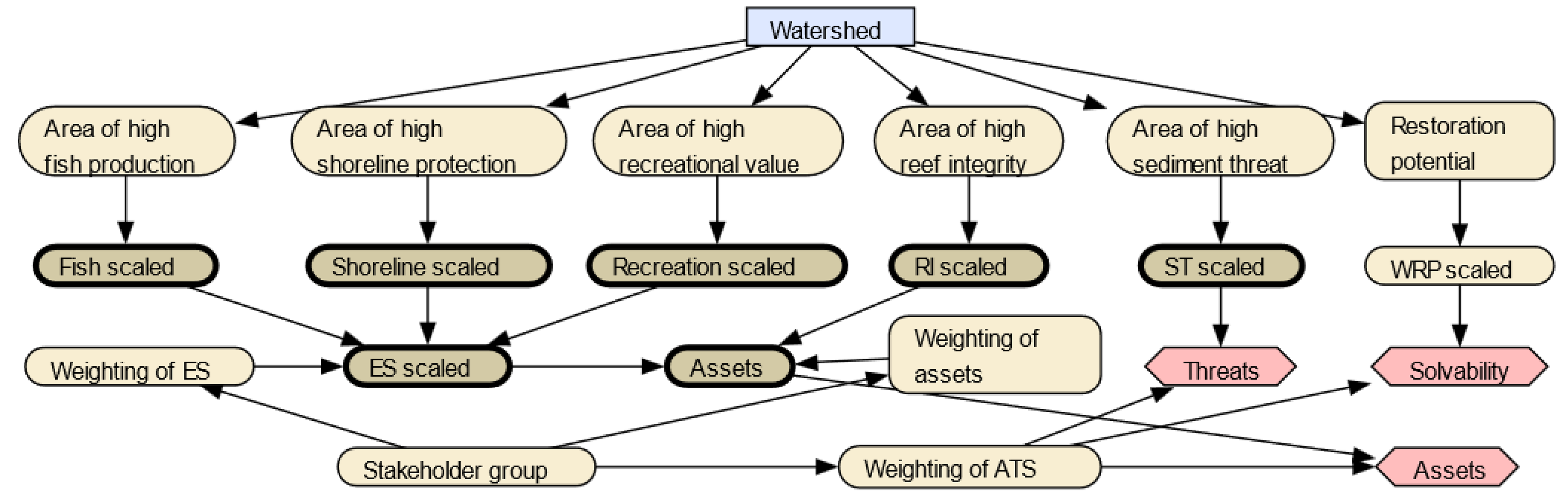
In the example, "Human use" sub-objective has three additional sub-objectives to define it for fisheries, shoreline protection and recreation.



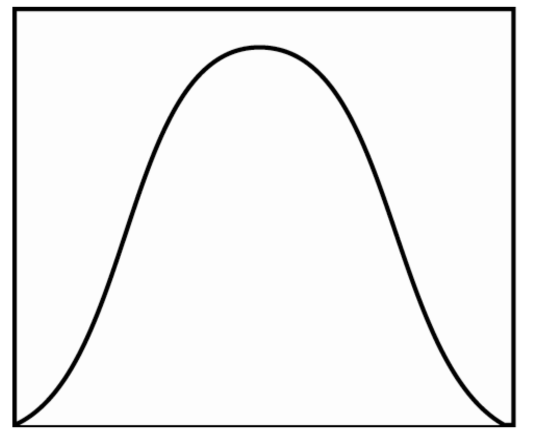
2 Identify management units

The **management units** are spatial areas to be prioritized. For assessing spatial priorities, management units must be selected as nonoverlapping, bounded and useful for decision making (Hajkowicz and McDonald 2006; Alvarez-Guerra et al. 2009). Management units must be comparable and reflect the decisions under consideration for meaningful comparisons. The size of management units can be vastly ranging from regions to grid cells. In this example, they are watersheds to be prioritized for environmental protection initiatives.

3 Construct network structure

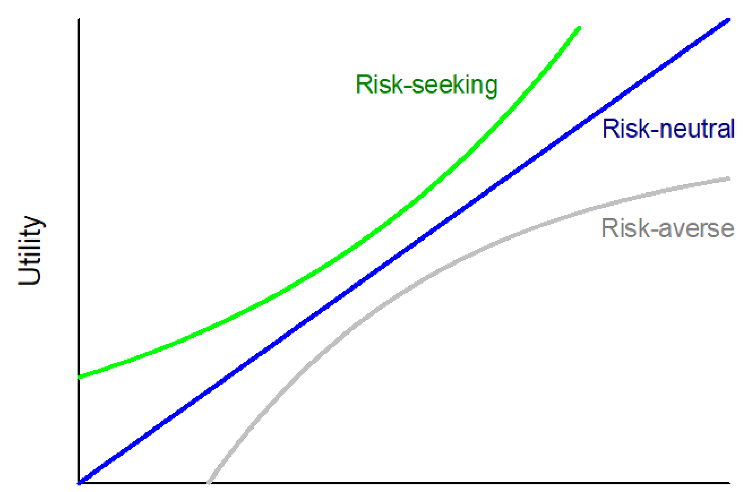


4 Construct probability distributions



Probability distributions must be constructed for each spatial criteria and every management unit. They can be further developed in the network with additional parent nodes between the management units and the criteria node or as interactive effects with the parent node. Distribution types depend on the criteria being assessed and the information used to establish the probabilities. With deterministic values, the output would be represented as 100% or 0% probabilities depending on the state outcome that is determined. For our case study, probabilities come from modeled output, spatial extrapolations, or spatial location uncertainties.

5 Construct utility functions



After the probability distributions are derived, **utility functions** must be constructed for the outcomes. The utility function scales the distributions from 0 to 1 with intermediate values given a number in between. Linear utility functions are usually appropriate; however, risk aversion can lead to deviations. The general shapes of three different types of functions for an attribute that increases in utility over its range is demonstrated to the right. For continuous distributions, utility functions may be bounded over a credible interval such as from 0 to 99% to capture the value of likely outcomes.

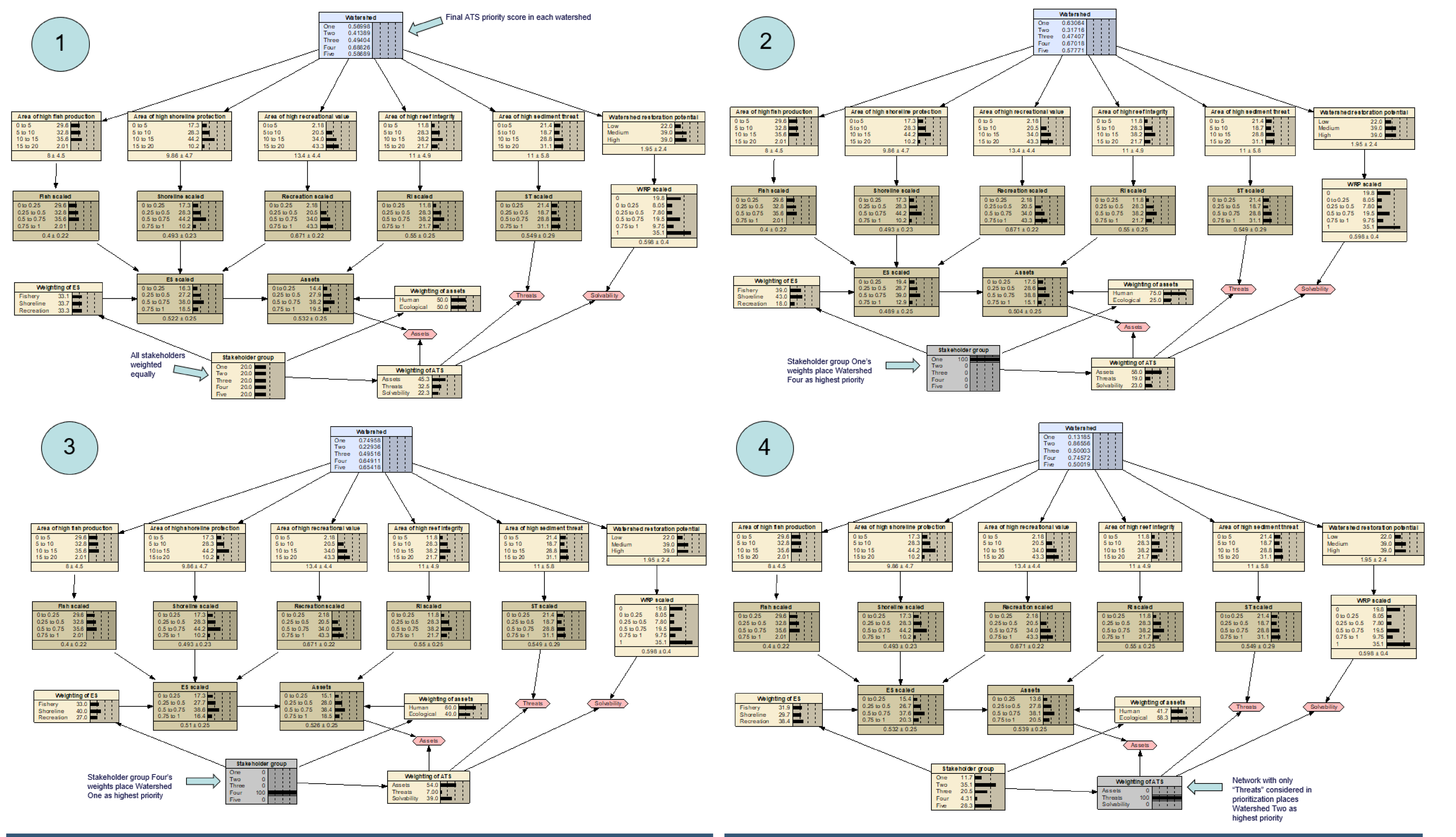
6 Weight the branches of the hierarchy

All branches of the hierarchy should be weighted with should be weighted to describe their relative importance to different stakeholders. They could be weighted equally, or alternatively some components may be more important than others. Thus, on the example hierarchy in Step 1, the following branches would require weights-

- The Assets, Threats, and Solvability fundamental objectives
- The Ecological Value and Human Use Value sub-objectives

In the network itself, we also weight three Human Use Value sub-objectives in addition to the above. The weights are represented as probabilities. **Swing weighting** is an appropriate procedure for determining weights (von Winterfeldt and Edwards 1986).

Demo Model- Coastal watershed prioritization



Conclusions

- The ATS hierarchy allows organizing and evaluating the information needed for risk prioritization decisions
- For spatial analysis with ATS, the decision should be at a screening level and focused on prioritizing regions or areas
- Adding Bayesian networks to the ATS framework allows consideration of uncertainty in the criteria
- The proposed networks in this presentation are useful for incorporating the weightings of multiple interest groups in the ATS hierarchy and evaluating their impact on the prioritization
- Moreover, the hierarchical structure can also be used to evaluate which management units are favored when the weights shift towards assets, threats, solvability or sub-objective branches of the hierarchy

References

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