BAYESIAN NETWORKS IN ENVIRONMENTAL PLANNING

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Environmental management increasingly requires **participatory and integrated approaches** that support informed decision making and can at the same time deal with **uncertainties**. A modeling approach that can handle these issues and has recently become more popular in environmental modeling and management are **Bayesian networks** (BNs) (UUSITALO 2007). A BN is a model of a real system that **graphically** represents the elements and connections of the system as a **probabilistic causal network**. A key characteristic of BNs is the possibility to include information from different sources. The results of the network are given as probability distributions (BROMLEY 2005).

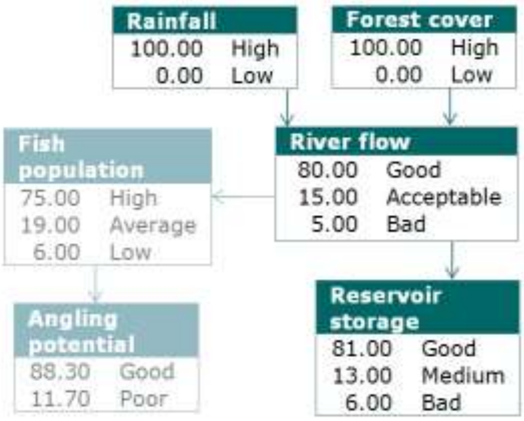
A BN consists of three main elements: **System variables** (nodes), the **causal relationships** between the nodes (directed links) and the **probability tables.** The variables can be of any type (physical, environmental, social, etc.) and any data form. To each variable a number of states this variable might possibly take is assigned. The input for the top most variables is entered by the user and can be derived from existing conditions or assumptions for scenarios. Based on this input, the probable states of the following variables are calculated using Bayes' theorem (ibd.). An example is given in Figure 1.

BNs can be used as a predictive tool to assess impacts or risks of certain actions, or as a diagnostic tool, to look for causes and drivers (DÜSPOHL et al. 2012). The structure of a BN and its design process offer many possibilities to **include stakeholders** in its development. Some advantages are:

- BNs are designed to integrate knowledge and information from different fields
- the design process of a BN is usually iterative and undertaken in small steps
- no expert knowledge in statistics or mathematics is needed to set up and use a BN (BROMLEY 2005).

BNs have already been commonly used in the fields of medicine and artificial intelligence for many years. In the context of environmental management BNs can for example be applied in the fields of surface and groundwater management, ecology and wildlife population viability and climate change on different planning levels. Especially on higher levels the main questions concern possible causalities and the probability of potential (cumulative) impacts, whereas on the lower levels causalities are usually known and the aim of a BN is mainly to support management decisions and to optimize procedures (BARTON et al. 2012).

Overall the use of Bayesian networks has the potential to **support and improve environmental planning** in a broad variety of different application fields where uncertainties and the need for stakeholder integration have to be handled.



CPT ‚Reservoir storage'		River flow		
		Good	Acceptable	Bad
Reservoir storage	Good	0.9	0.6	0
	Medium	0.1	0.3	0.1
	Bad	0	0.1	0.9

Fig. 1: Example for a simple BN (adapted from BROMLEY 2005)

The example in Figure 1a shows a BN in which the angling potential and the reservoir storage are calculated in dependence from several variables. The conditional probability table for the reservoir storage shows how probable it is that the reservoir storage will be in a certain state depending in the state of the river flow. For example if the river flow is bad, there is a 0 % probability of a good reservoir storage and a 90 % probability of a bad reservoir storage. CPTs are set up for all variables that depend on other variables, i.e. behind the diagram of Figure 1, there are CPTs for the nodes 'Fish population, 'River flow', 'Angling potential' and 'Reservoir storage'. The values for 'Rainfall' and 'Forest cover' are entered by the user. This has been done in the presented example: both variables have the 'status' high with a 100% certainty. This information can for example be derived from observations (I see that it rains and that there is a high forest cover – how high is the angling potential under these conditions?). In the example these conditions result in a probability of 88.3 % for a good angling potential, and 11.7 % for a poor angling potential.

References

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