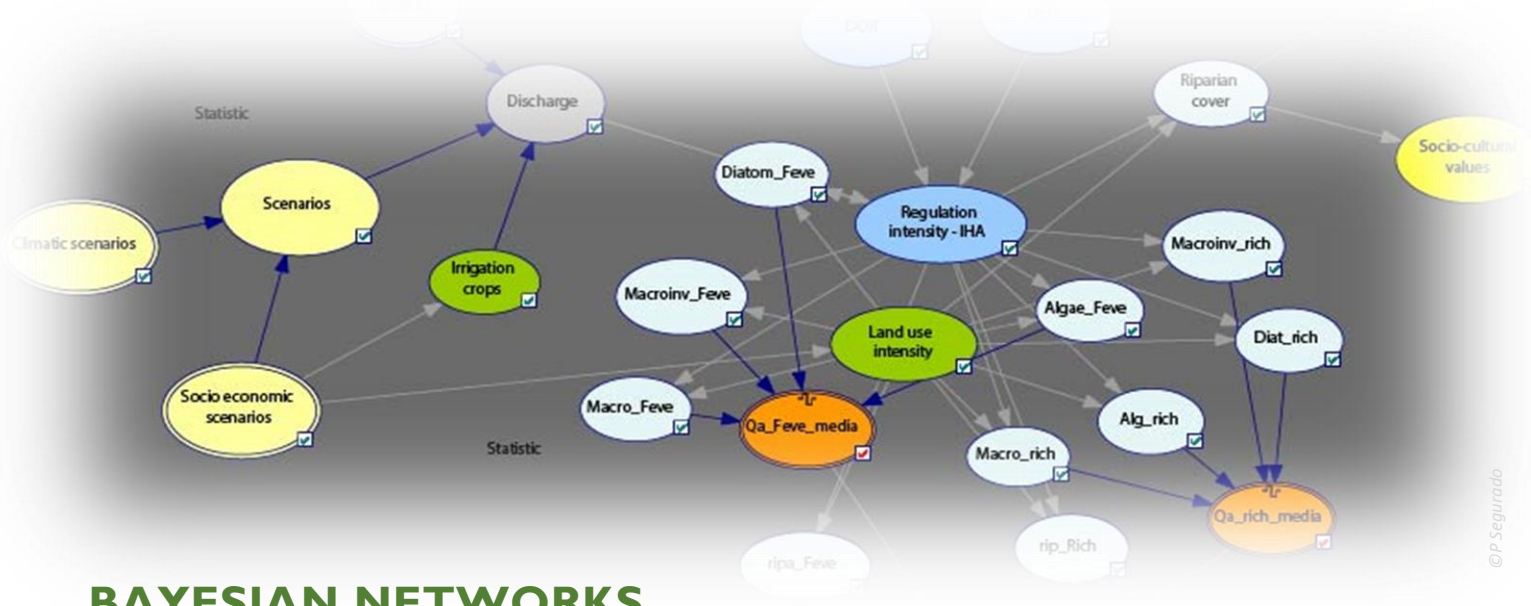
RIVEAL PROJECT

RIPARIAN FOREST VALUES AND ECOSYSTEM SERVICES – BAYESIAN NETWORKS

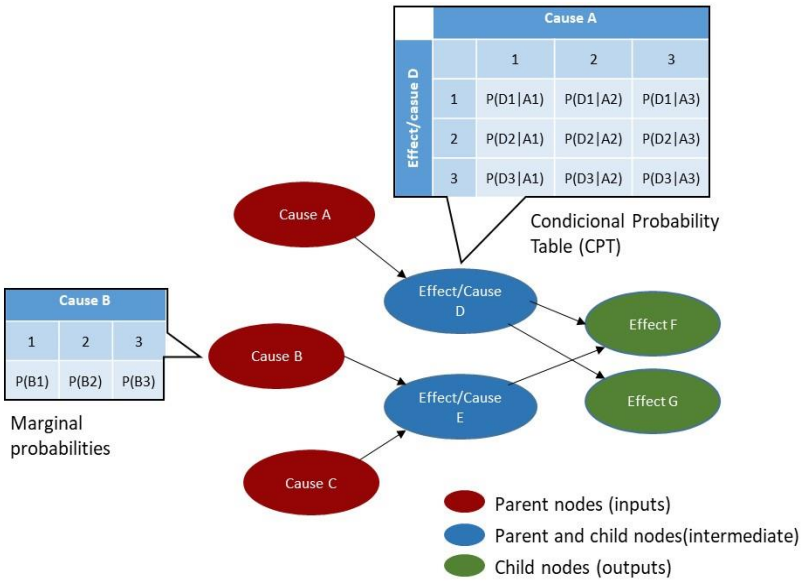


BAYESIAN NETWORKS ARE …

… graphic models that represent cause-effect relationships among a set of variables. Many natural processes can be modeled through influence diagrams, which establish causal relationships among variables. Bayesian networks are often used to produce such diagrams when relationships are complex and a large number of interactions between variables are present. These models rely on the Bayes theorem to model the propagation of probabilities along the influence network, hence their designation.

FEATURES

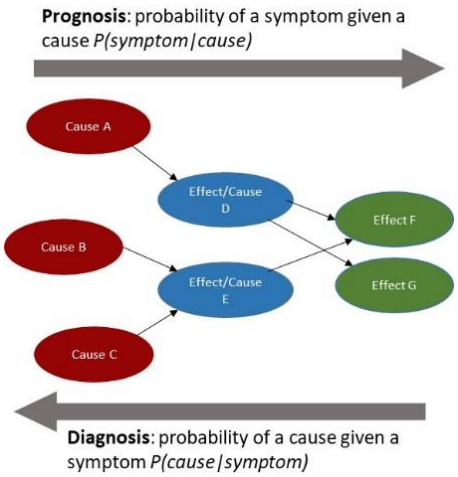
- They are directed and acyclic graphs, that is, do not allow to incorporate feedback loops.
- They assume static effects in time (non-dynamic).
- They are formed by **nodes** (or vertices), which represent variables, and unidirectional **arcs** (or edges), which represent causal relationships between pairs of variables in the direction of influence (from **parent nodes** to **child nodes**).
- The **Input nodes** are those that are conditionally independent (the probabilities of each state can result, for example, from measurements in the field), the **intermediate nodes** are those that depend on other nodes (input or intermediate) and the **output nodes** are those that do not have any influence in any node in the network.
- The relationships among nodes are defined by **Conditional Probability Tables** that establish the probabilities of each of the effects (states of the variable of the child node) taking into account each state of the variable that influences them (state of the variable of the parent node).



Example of a Bayesian Network with three input nodes, two intermediate nodes and two output nodes. Each variable contains three states. As an example, we represent two tables associated with an input node (marginal probabilities) and an intermediate node (conditional probabilities) where, for example, the notation P(D1|A2) means Probability of D taking the value 1 given A taking the value 2.

ADVANTAGES

- The model translates into a simple and intuitive graphical representation;
- It explicitly incorporates the associated uncertainty;
- It allows the integration of information of different nature: empirical data, statistical models, mechanistic models, meta-analyses, surveys and expert knowledge;
- It allows to perform both prognostic (for example, knowing the probability of a symptom given a certain cause), and diagnostic analyses (for example, knowing the probability of a cause given a certain symptom);
- Allows you to update probabilistic beliefs as new information about a particular link becomes available.



Example of a Bayesian Network and the two different possible directions for its utilization (prognosis and diagnosis).

BAYESIAN NETWORK DEVELOPMENT

The development of a Bayesian Network involves three main steps:

- Elaboration of a conceptual model, which defines the structure of the cause-effect network using an influence diagram. This is usually defined by experts, taking into account the available information, but it can also be defined automatically from the data.
- Assign probabilities to the different states of each variable. This step usually involves prior discretization of the variables into different states and the construction of marginal probability tables (input nodes) and conditional probability tables (intermediate or output nodes).
- Model evaluation, involving its validation based on independent data and a sensitivity analysis to assess how network uncertainty can affect the output nodes.

APPLICATIONS IN WATER RESOURCES MANAGEMENT

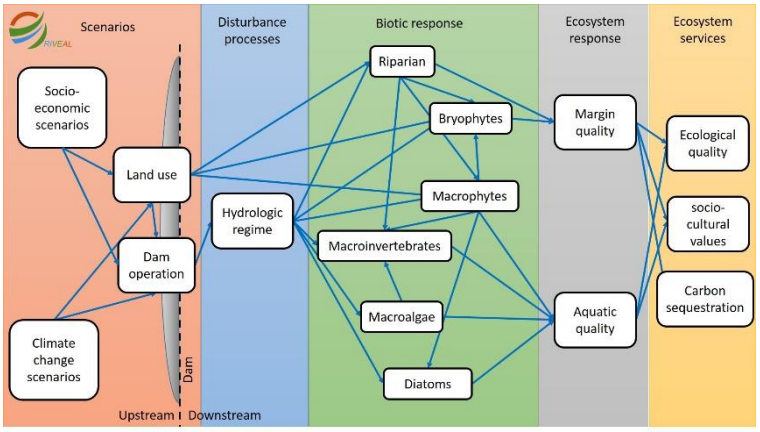
The intuitive graphical representation, the straightforward user interaction with the Bayesian network and the prompt uncertainty assessment of a given decision, makes this tool very advantageous in the area of natural resources management. Indeed, its use in different aspects of aquatic resources management has been growing in the last two decades, namely for the assessment of water quality under different management, land use and climate changes scenarios.

CONTRIBUTION TO RIVEAL

The RIVEAL Project's Bayesian Network aims to provide an integrative tool for predicting the effect of different socio-economic and climate change scenarios on three groups of ecosystem service values in riparian systems affected by dams: ecological quality, socio-cultural values and carbon sequestration. By introducing changes to different scenarios in the input nodes, it becomes possible for the environmental manager to know the response of ecosystems and their services, and make more effective decisions to mitigate the effect of disturbances.

The Bayesian Network will consist of five components:

1. The socio-economic and climate change scenarios component that will mainly affect land use and dam operation.
2. The resulting disturbance processes, which, in the system in question, are assumed to arise mainly from changes in the hydrological regime and land uses.
3. The biotic response of the different biological indicators considered.
4. The ecosystem response to changes in the biotic component.
5. The response of ecosystem service values.



Preliminary conceptual model for the development of the Bayesian Network of the RIVEAL project.

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