RIPA-1 : First International Conference on Riparian Ecosystems Science and Management

Bayesian Networks and expert knowledge in riparian ecosystem management

Vieites-Blanco, C., Gomes Marques, I., Segurado, P., Jung, T., Almeida, H., Biurrun, I., Corcobado, T., Costa e Silva, F., Diez, J. J., Dufour, S., Faria, C., Ferreira, M.T. , Ferreira, V., Jansson, R., Machado, H., Marçais, B., Moreira, C., Oliva, J., Pielech, R., Rodrigues, A. , Soares David, T., Solla, A., Marques, M., Barrento, M.J., Fernandes, M.R. , Cupertino, A. , Rodríguez-González, P. M.

Funding

FCT Fundação para a Ciência e a Tecnologia

ALNUS

Coordinating institution

cef Centro de Estudos Florestais

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

U LISBOA | UNIVERSIDADE DE LISBOA

Participating institutions

Mendel University in Brno

PhytOphthora Research Centre

University of Agriculture in Krakow

Universidad de Extremadura

Universidad del País Vasco Euskal Herriko Unibertsitatea

Universidade de Coimbra

Université Rennes 2

INIAV

Umeå University

Universitat de Lleida

Universidad de Valladolid

iuFOR Gestión Forestal Sostenible

Université de Lorraine

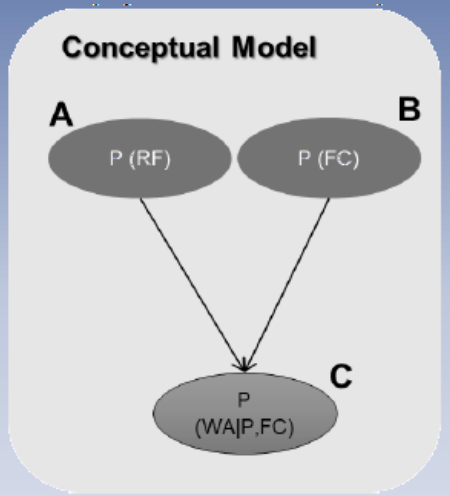
INTRODUCTION

Bayesian Networks *in riparian ecosystem management*

What are Bayesian Networks (BN)?

Probabilistic graphical models that determine the cause-effect relationships between variables (nodes); links between parent and child nodes are defined by a set of conditional probabilities

CONCEPTUAL MODEL



Nodes States

A	Rainfall (RF) states	Range (mm)
	Low	300-600
	High	600-900

B	Forest Cover (FC) states	Range (%)
	Low	50-75
	High	75-100

C	Water Availability (WA) states	
	Low	
	High	

- **Causal relationships between variables**
- **Unidirectional arrows (no loop back)**
- **Node states: categorical / discretized**

CONDITIONAL PROBABILITY TABLES (CPTs)

Parent Nodes

Probability Tables

	P (RF)
Low	0.550
High	0.450

	P (FC)
Low	0.600
High	0.400

Child Node

Conditional Probability Table

RF	FC	P (WA=High|RF,FC)	P (WA=Low|RF,FC)
High	High	0.950	0.050
High	Low	0.940	0.060
Low	High	0.290	0.710
Low	Low	0.001	0.999

- **Quantitative description of the relationships**
- **Avoid complex models that imply complex CPTs**

Ames, D. P., Neilson, B. T., Stevens, D. K., & Lall, U. (2005). Using Bayesian networks to model watershed management decisions: an East Canyon Creek case study. *Journal of hydroinformatics*, *7*(4), 267-282.

Bayesian Networks *in riparian ecosystem management*

What can BN offer to research and management of riparian ecosystems?

Interdisciplinarity

- **Integrate multiple system components**
- **Include different information sources**

Deal with limited data

- **Integrate different types of information (e.g. expert judgement, literature review, empirical data)**
- **Allow progressive improvement and continuous updating to include new advances in the state-of-the-art or new data**

Communication to stakeholders

- **Graphical output easily interpretable**
- **Modular architecture**

Barton, D. N., Saloranta, T., Moe, S. J., Eggestad, H. O., & Kuikka, S. (2008). Bayesian belief networks as a meta-modelling tool in integrated river basin management—Pros and cons in evaluating nutrient abatement decisions under uncertainty in a Norwegian river basin. Ecological economics, 66(1), 91-104.
Chen, S. H., & Pollino, C. A. (2012). Good practice in Bayesian network modelling. Environmental Modelling & Software, 37, 134-145.

INTRODUCTION

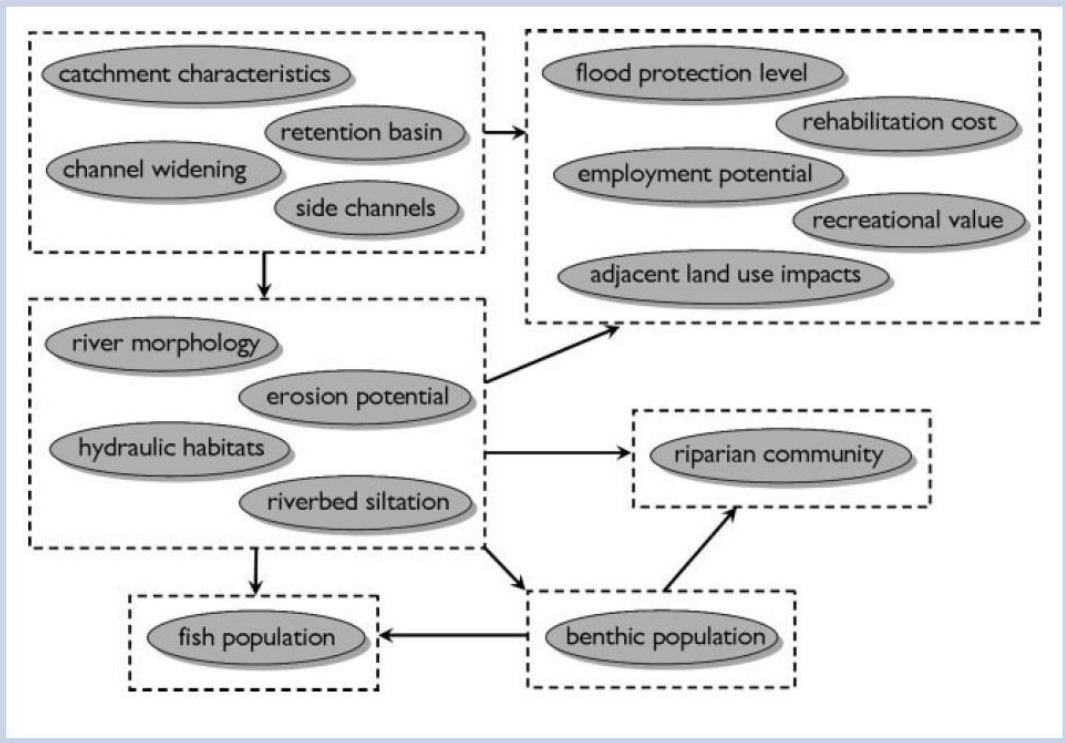
Bayesian Networks *in riparian ecosystem management*

Some examples….

Integrated Environmental Assessment and Management — Volume 8, Number 3—pp. 462–472
462

A Bayesian Network Model for Integrative River Rehabilitation Planning and Management

*Mark E Borsuk, *†,‡ Steffen Schweizer,†,§ and Peter Reichert†,||*
†Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland
‡Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, USA
§Kraftwerke Oberhasli AG, Meiringen, Switzerland
||ETH Zürich, Swiss Federal Institute of Technology, Zürich, Switzerland



ECOLOGICAL ECONOMICS 66 (2008) 91–104
available at www.sciencedirect.com
ScienceDirect
www.elsevier.com/locate/ecolecon
ELSEVIER

ANALYSIS

Bayesian belief networks as a meta-modelling tool in integrated river basin management — Pros and cons in evaluating nutrient abatement decisions under uncertainty in a Norwegian river basin

D.N. Barton[a,], T. Saloranta[a], S.J. Moe[a], H.O. Eggestad[b], S. Kuikka[c]*
[a]Norwegian Institute for Water Research (NIVA), Gaustadalléen 21, NO-0349 Oslo, Norway
[b]Norwegian Institute for Agricultural and Environmental Research (Bioforsk), Fr. A. Dahlsvei 20, NO-1432 Ås, Norway
[c]FEM Group, University of Helsinki, Department of Biological and Environmental Sciences, P.O. Box 56, FI-00014 University of Helsinki, Finland

Participatory tools *for expert knowledge*

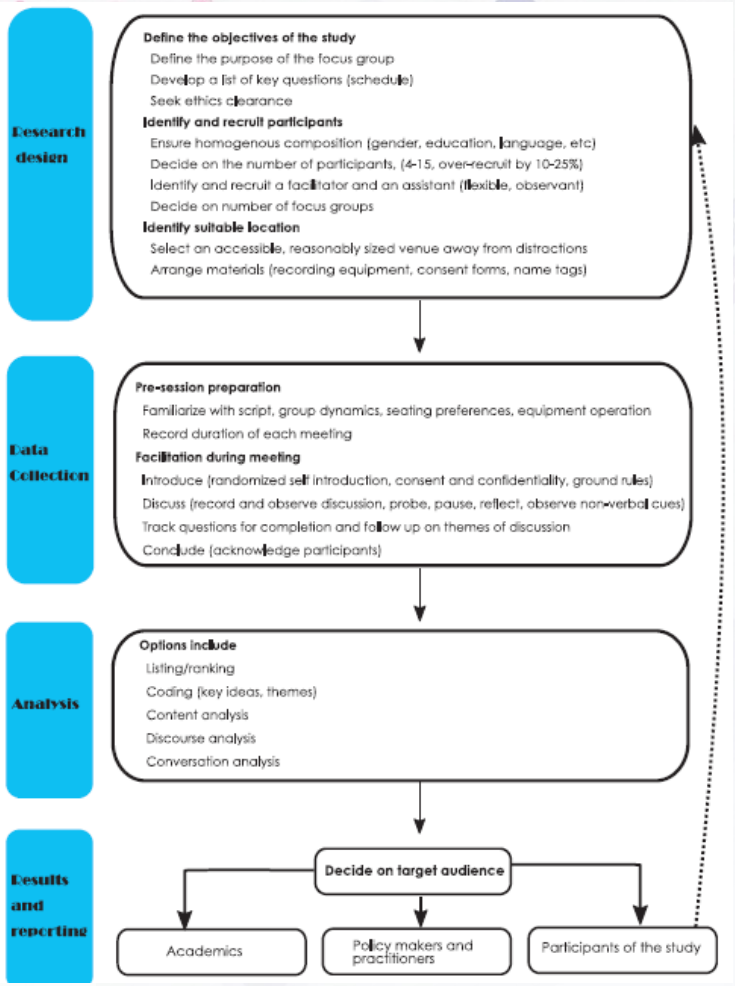
Some participatory tools…

- **Interviews, Delphi method**
  - ***Statistically representative sample of a broad population***

- **Focus group**
  - ***Selected group of individuals that discuss a particular topic***

Focus groups

- **Dedicated groups of experts in target paths of the network that match their expertise**
- **3-20 participants + moderators**
- **Perspectives regarding conservation; assessment of conservation; challenges of resource management interventions….**



Nyumba et al. 2018

O.Nyumba, T., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and evolution, 9(1), 20-32.

CASE STUDY

ADnet – *predicting vulnerability to alder decline*

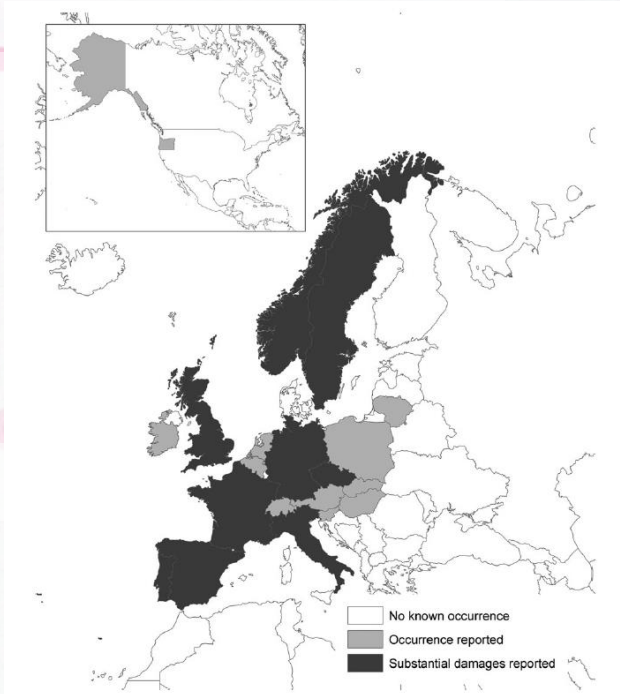
Alder decline in Europe

The invasive pathogen *Phytophthora xalni*

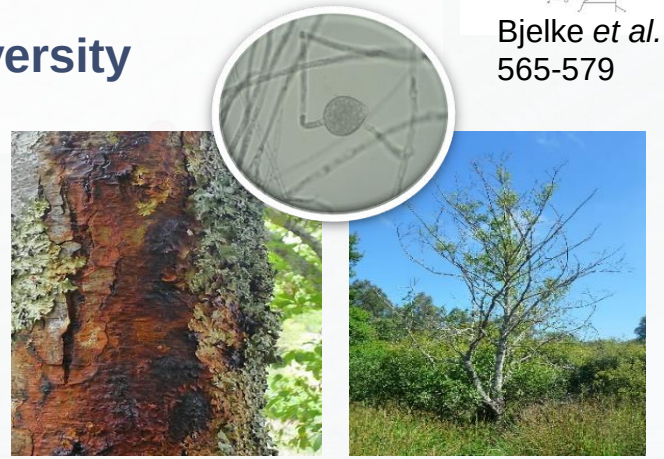
- Oomycete; 90s in N Europe; now extended in C and S Europe
- Massive decline and mortality

Threat to alder riparian forests

- Emergent diseases add to previous threats by human activities and climatic alterations
- Threaten ecological functions (e.g. N_2 fixation, biodiversity maintenance)



Bjelke *et al.* 2016 Freshwater Biol 61(5): 565-579



CASE STUDY

ADnet – *predicting vulnerability to alder decline*

What is the ADnet (ALNUS DECLINE net)?

- **Predict the vulnerability of alder forests to *P. xalni***
- **Field data, bibliography and expert knowledge**
- **Panel of experts (19 researchers, 12 institutions, 6 countries) in plant pathology, riparian ecology, ecophysiology**

CASE STUDY

ADnet – *predicting vulnerability to alder decline*

Workflow

ADnet v1

Introduction to methodology

First expert meeting:

- Focus groups discussion

1/ Description of the subnetwork (moderators)
2/ Addition/modification/removal of nodes or causal relationships (3 separated rooms)
3/ Final discussion of the new subnetworks
4/ Focus group wrap up (general discussion)

January 2021

Meeting outcomes & next steps

ADnet v2

Expert contribution (data…)

ADnet v3

Second expert meeting:

- ADnet validation

1/ Validation of ADnet v2
2/ Definition of missing probabilities
3/ Conclusions and next steps

April 2021

Expert contribution (data…)

Data modelling

ADnet finalization and evaluation *ongoing*

Final ADnet

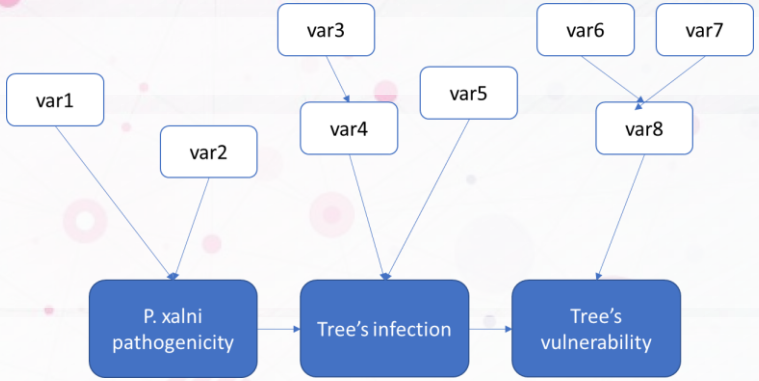
CASE STUDY

ADnet – *predicting vulnerability to alder decline*

What were the main limitations encountered?

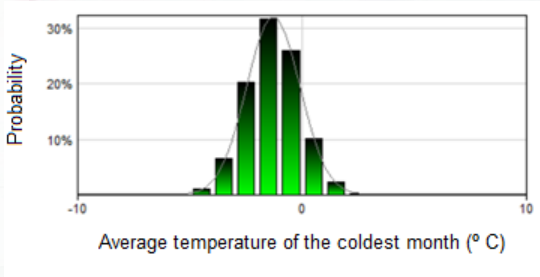
High complexity of the Conditional Probability Tables

- Division of the model in submodels
- Synthetic nodes
- Limit the number of links to a child node to 3-4



Discretization of continuous variables

- Probabilistic nodes (discrete variables)
- Equation nodes (equation that describes the interaction of continuous variables)
- Deterministic nodes (probabilities 0 or 1)



Temporal and geographical scale

- Model scales must be defined to homogenize the temporal and spatial scales and the resolution of the nodes (specially challenging when integrating different data)
- Geographical filter node

Terrestrial biomes	Country
Tundra	Western Sweden
Boreal Forests/Taiga	Eastern Sweden
Temperate Broadleaf & Mixed Forests	Central Europe (France, Germany, Austria, UK, Northern Italy) and Northern Iberian Peninsula
Temperate Conifer Forests	Northern Italy
Mediterranean Forests, Woodlands & Scrub	Southern Portugal, Southern Spain, Central and Southern Italy
Temperate Grasslands, Savannas & Shrublands	Romania, Ukraine, Bulgaria

Specific area of knowledge with few experts and available data

- Focus groups

Conclusions and Prospects

High potential of BN and FG to support riparian ecosystem management

- Deal with limited and heterogeneus data, interdiscipinarity
- Graphical output easily used by stakeholders for ecological risk assessemnt, management assessment, etc.

Case study - Alder Decline net (ADnet)

- Alder decline due to *P. xalni* – need to prioritize areas for conservation to facilitate management
- Predict the vulnerability of alder forests to the pathogen, taking into account interacting abiotic, biotic and social factors
- Interdisciplinar and international panel of experts – 2 consultation rounds

Leasons learned from the case study

- Limit ADnet complexity to facilitate CPTs completion
- Inclusion of equation nodes for continuous variables
- Focus groups to deal with very specific information and reduced availability of experts and data

Acknowledges

Thank you for your attention!

This study is funded by Portuguese Foundation for Science and Tecnology (FCT) through ALNUS project (PTDC/ASP-SIL/28593/2017). Inês Marques was funded by FCT with the grant SFRH/BD/133162/2017, Patricia M Rodríguez-González was supported by FCT through the CEEC Individual programme grant number 2020.03356.CEECIND, and CEF by UIDB/00239/2020.

Contact: cristinavieites@isa.ulisboa.pt

FCT Fundação para a Ciência e a Tecnologia

ALNUS