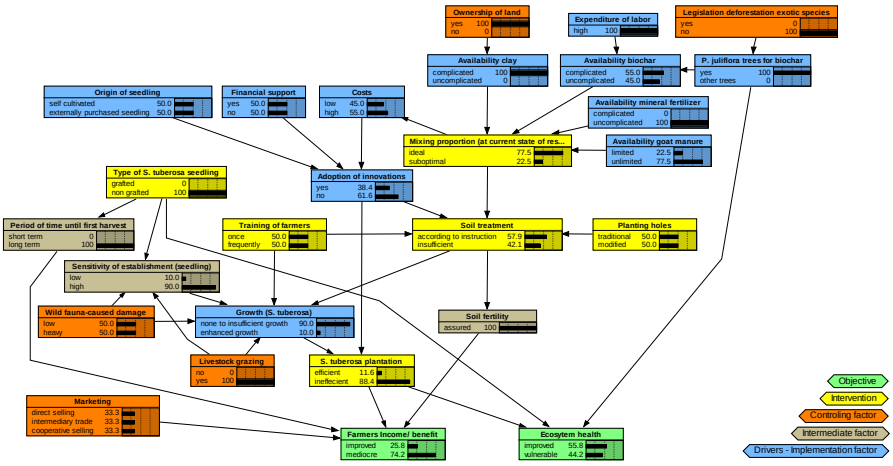
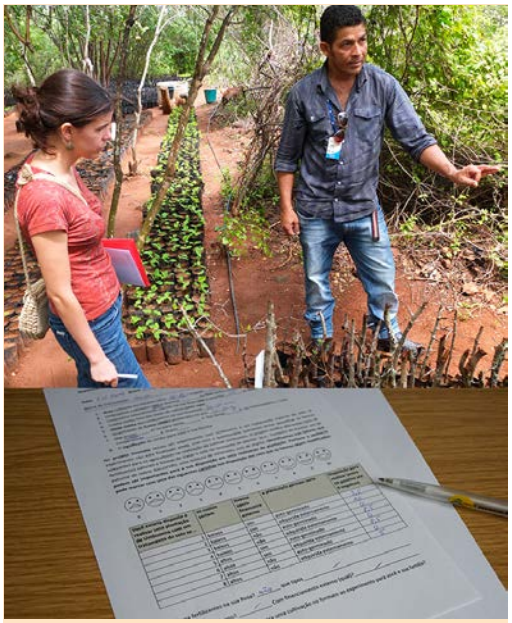




left: Model and scenario development using Bayesian Network Approach (Photo: Liron Steinmetz)
right top: Stakeholder interview in a fruit cooperative. (Photo: Liron Steinmetz)
right bottom: Interview questionnaire. (Photo: Liron Steinmetz)

Bayesian Network Approach

Brazil - *Abordagem com Redes Bayesianas*

Assessment of the probability and effectiveness of management options or innovations to describe cause-effect-relationships and to make recommendations for action on sustainable land management in the Itaparica region in Northeast Brazil.

The study focus was on the determinants behind the adoption of innovations developed under a scientific project. The specific innovation analysed was intended to benefit both the environment and local smallholder farmers: namely cultivating a multi-purpose, low-growing, to the prevailing harsh semiarid environment well-adapted tree species (*Spondias tuberosa* L. – so called *umbuzeiro*). The assessment method was selected as it allows the combination of qualitative and quantitative data, and can be applied even in data-scarce situations. Moreover, it allows downscaling from a broad overview to small-scale management.

Knowledge is collected from different disciplines to support decision-making through the inter- and transdisciplinary approaches of constellation analysis and Bayesian networks. A Bayesian Network (BN) is a probabilistic graphical model that represents a set of variables (elements, nodes) and their conditional dependencies. There are three input components to a Bayesian Network: (a) a set of elements representing factors relevant to a particular environmental system or problem, (b) the links between these elements, and (c) the conditional probability tables (CPTs) behind each node (element) used to calculate the state of the node. Collected data and ratings are arranged in a hierarchical Bayesian Network model in Netica software (Netica 5.12 - freeware up to 15 nodes).

The creation of a Bayesian Network model is as follows: the objectives and necessary interventions for the innovation process aimed at sustainable management are characterized, with scientists arranging a conceptual diagram, including the mapping of elements. States of the nodes are determined through study of the literature and expert consultation (by scientists, stakeholders and experts on related topics). In a final step, a sensitivity analysis is performed on the Bayesian Network to highlight crucial nodes with the highest influence on objectives in order to derive actions to be recommended.

Stakeholder participation is the core process of designing Bayesian Networks. In pre-consultations stakeholders help identifying major influencing factors and relationships. Assessments are compiled in interview sessions enabling the states of the nodes to be quantified later. In this case study, the stakeholders were farmers, farmer-supporting institutions, and expert in soils, vegetation and crops.

Location: Pernambuco, Brazil, Itaparica Reservoir, Petrolândia
Approach area: > 10,000 km^2
Type of approach: project/programme based
Focus: Mainly on conservation with other activities
WOCAT database reference: A_BRA005en
Related technology: none
Compiled by: Verena Rodorff, Berlin Institute of Technology, Environmental Assessment and Planning Research Group, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de
Date: 20th May 2014, updated June 2016

Problem, objectives and constraints

Problems:
Low agricultural productivity and production, recurrent droughts. Little secured access to water. Almost no regeneration of endemic tree species. Increased degradation of the caatinga biome and its natural vegetation in the northeast of Brazil. Caatinga means “white forest” and is a xeric shrubland and thorn forest, which consists primarily of small, thorny trees that shed their leaves seasonally.

Aims / Objectives:
The principle of Bayesian Network modelling is the integration of multiple issues and system components, where information from different sources can be integrated, while also handling missing data and uncertainty. The outcome may be recommendations that support local management decision-making. As the method is strong in transdisciplinary knowledge integration, it has the potential to become one of the core methods in environmental management.

Constraints addressed

	Constraints	Treatments
Technical	Bayesian Network programmes need a licence. Questionnaires need to be easy and user friendly.	Use available free programmes. Use of visual aids such as smileys for evaluation to make questionnaire more comprehensible.
Workload	Work on and define clear objectives and model structure before developing the questionnaire.	Data collection through a review of literature and surveys. Discuss model structure with experts.
Financial	For stakeholders, financial support is necessary to implement innovations.	Potential for financial support could be through national small-scale farmer programs; suitable government-sponsored credit programs, public and governmental institutions such as bulk purchasers of agricultural commodities (for instance SEBRAE in Brazil).
Legal / land use and / water rights	Illegal cutting of native trees for biochar production.	Reinforcement of rules and regulations. The forest code prohibits cutting native trees. The native *umbuzeiro* tree is sacred for locals.

Participation and decision making

Stakeholders / target groups


SLM specialists / agricultural advisors


politicians / decision makers


land users, groups

Approach costs met by:

– International: German Federal Ministry of Education and Research (BMBF)	100%
Total	**100%**

Annual budget for SLM component: US$ < 2,000. Project funds covered all of the relatively low expenses; hypothetically the approach can be used almost free of charge.

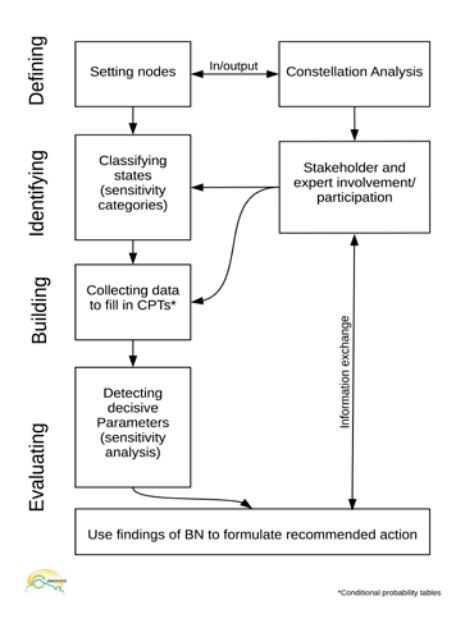
Decisions on choice of the Technology: The approach was initiated by scientists.
Decisions on method of implementing the Technology: There is still no formal decision by stakeholders on the technology and its implementation.
Approach designed by: International specialists.
Implementing bodies: International, local community / land users, local government (district, county, municipality, village etc.)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Passive	Interviews
Planning	None	None
Implementation	Interactive	Interviews
Monitoring/evaluation	Interactive	Interviews
Research	None	None

Differences between participation of men and women: No

Involvement of disadvantaged groups: Yes, great. Farmers of a resettlement community on dryland and representatives of the indigenous Pankararu tribe.



Organogram:
Simplified work flow of Bayesian Network (BN) showing different steps:
- Defining: apply or use already applied constellation analysis (see A_BRA003en) for information and visualization of node setting for the BN model and for stakeholder identification.
- Identifying: clarify objectives, implementation factors, interventions, intermediates and controlling factors. Give every node a state, e.g. date, temperature range, amount of precipitation, or a classification: high / low…
- Building: Collect data to fill the conditional probability tables (CPTs) behind every node. Prepare questionnaires, ask experts and conduct a literature search. Avoid too much states and no more than four nodes indicating the next node. Finish the model by entering all data in a programme (e.g. Netica).
- Evaluating: Compare different scenarios by changing the state of inputs (e.g. from low to high). Show a baseline (without changes), a most improved and least improved scenario to justify recommendations. Finally, hand over recommended actions to stakeholders.

(Liron Steinmetz and Verena Rodorff)

Technical support

Training / awareness raising: Training was provided for land users, field staff/agricultural advisors. Training was through demonstration areas, by workshops, site visits / farmer-to-farmer visits. Training focused on detecting decisive factors to develop an ideal scenario of implementation/ adoption by land users. For the participants it was interesting to participate in preparing a joint view of their “action space” - this is generally known in its constituent parts though not with its major interconnections and complex completeness. Participants especially acknowledged the value added of this.
Advisory service: To apply the BN approach for other innovations, a guideline for BN can be of help.

Research: Research was very important to this approach. Topics covered include sociology, technology, economics / marketing, ecology. Mostly on-station research but also on-farm research took place. Research on the situation of local action and governance was a major driver for the workshops. University project members prepared and held the workshops, while also interpreting and integrating results across a number of different workshops.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Voluntary
Input: None
Credit: Credit was not available
Support to local institutions: Yes, great support by training. Decisive factors for the adoption of innovations were identified, including favourable cultivation techniques for the *umbuzeiro* tree (e.g. soil additives).

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Regular measurements by project staff: Monitoring of *umbuzeiro* plantations on an experimental plot.
technical	Ad hoc observations by project staff, land users: Test plantations within family farmed land. Regular measurements by project staff: Monitoring of *umbuzeiro* plantations on an experimental plot.
socio-cultural	Regular observations by project staff, land users: the indigenous Pankararu tribe and smallholders involved.
economic / production	Regular observations by project staff, land users: Questionnaires. Regular measurements by project staff, land users: Calculated BN objective.
area treated	Regular observations by project staff: Selected innovation is limited to the area of caatinga vegetation.
no. of land users involved	Regular measurements by project staff: Number of participants in workshops and interviewees.
management of Approach	Regular observations by project staff: Feedback on approach by stakeholders, self-evaluation. Regular measurements by project staff, land users: Probability calculations based on the BN questionnaires

Changes as result of monitoring and evaluation: There were several changes in the approach. The iterative process of interviews of the BN approach leads to constant re-evaluation of the original network. There were no changes in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, great. The different scenarios tested under the BN highlighted the good probability of adoption, which then can support sustainable land management.
Adoption by other land users / projects: No. Unknown
Improved livelihoods / human well-being: Yes, great. The different scenarios tested under the BN highlighted the good probability of adoption, which can then benefit the livelihoods of adopters.
Improved situation of disadvantaged groups: Yes, moderate. The approach was conducted especially for small-scale farmers without sophisticated irrigation techniques, and also for the indigenous Pankararu tribe.
Poverty alleviation: Yes, little. Not immediately but a long-term influence is possible.
Training, advisory service and research:

- Training effectiveness:
  Agricultural advisors / trainers, politicians / decision-makers, land users, SLM specialists, planners: good
- Advisory service effectiveness:
  Technicians / conservation specialists, politicians / decision-makers, land users: good
- Research contributing to the approach's effectiveness:
  Greatly. BN's accuracy is closely dependent on the preceding research (existing literature data and quality of questionnaires filled).

Land/water use rights: None of the above in the implementation of the approach. Limited access to water within the study region was one of the main factors for assessing alternative agriculture methods via the BN approach. The approach did reduce the land/water use rights problem (moderately). The BN model offers alternative sources for soil additives where land use rights hinder availability.
Long-term impact of subsidies: Irrelevant to approach

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production; increased profitability, improve cost-benefit ratio; well-being and livelihoods improvement; environmental consciousness, morale, health; payments / subsidies.
Sustainability of activities: Yes the land users can sustain the approach activities without support. Lessons learnt (especially about the most favourable soil additive mixture) improved effectiveness of potential *umbuzeiro* tree cultivation. Stakeholder pool of BN-creation comprises business networking opportunities for land users.

Strengths and → how to sustain/improve	**Weaknesses and → how to overcome**
The combination of input variables from any given background is possible → It is recommended to use research results.	The statistical component of the Bayesian network approach can be hard to grasp for poorly educated stakeholder groups → Percentages of probability estimations can be translated into a visual representation (eg a gradual scale of emoticons).
Via Bayesian network changes to the modelled system can be tested. The space and potential effects of management options can be shown to decision-makers → Hand out results and show scenarios via presentations or reports	
Combining Bayesian networks with Constellation Analysis (see A_BRA003en) allows easy determination of major nodes of the model and supports the process of decision-making for sustainable land management activities; methods proved to be very transdisciplinary → Combination with Constellation Analysis helps to identify specific actors and to show complex situation as well as interest of stakeholders.	

Key reference(s):
http://www.innovate.tu-berlin.de/v_menue/subprojects/sp7_decision_support_approach_and_project_coordination/sp7_rm1_decision_support_approach/parameter/en/
• Rodorff V., Steinmetz L., Siegmund-Schultze M., Köppel J. (2015) Using Bayesian networks to depict favouring frame conditions for sustainable land management: Umbuzeiro-tree planting by smallholders in Brazil. Session: Methods, tools and impact applications. Tropentag 'Management of land use systems for enhanced food security - conflicts, controversies and resolutions', September 16 – 18, 2015, Humboldt-Universität zu Berlin, Berlin, Germany.
Contact person: Verena Rodorff, Berlin Institute of Technology (Technische Universität Berlin), Environmental Assessment and Planning Research Group, Secr. EB 5, Straße des 17. Juni 145, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de