Using Bayesian Networks (BNs) for Mapping Stakeholders Behaviours in Integrated Water Resource Management

with a Focus on Irrigated Agriculture in Al Batinah Region of Oman

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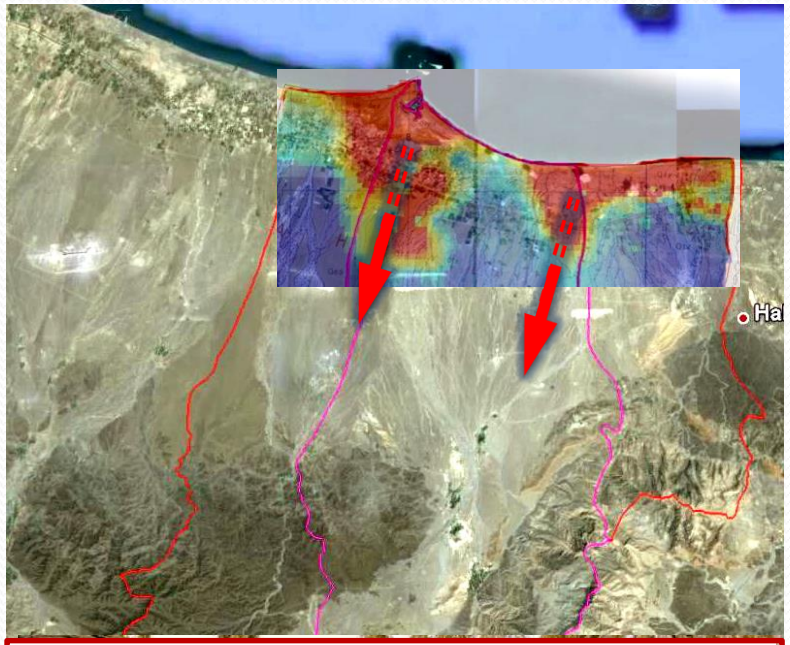
Overview

- Introduction (problem, objectives)
- Methods used
- Results & Discussion
- Conclusions
- Recommendations

Introduction

Study is focusing on a real management problem of the coastal agricultural region in a part of South Al Batinah in Oman

South Al Batinah agricultural area



Saline intrusion in coastal areas

Motivation and problem

Agricultural region → problem of over abstraction of fresh groundwater for irrigation along the coast.

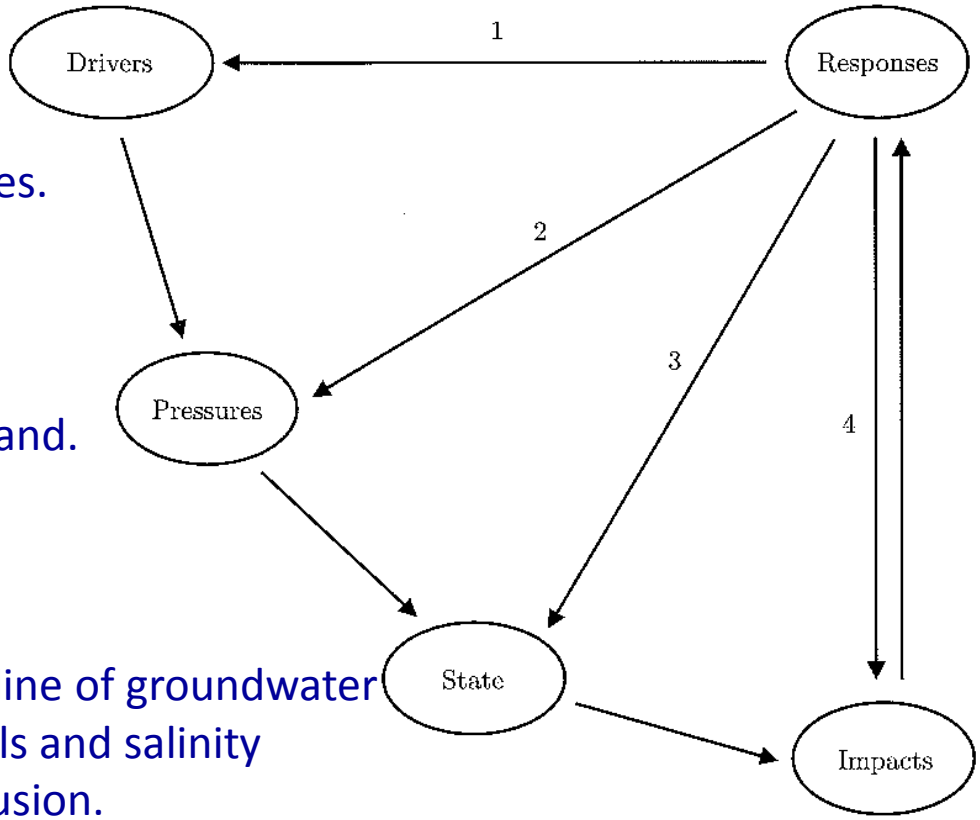
Problems → **Possible Solutions** → **Decisions should be made**

Introduction

Clarification by using the DPSIR framework
South Al Batinah catchment basin - AGRICULTURAL sector

- Practices followed by farmers.
- Abstraction rates exceeded recharge rates.

- Water resources are limited.
- Increase in water demand.
- Degradation of water quality and pollution problems.



Design & Implementation of measures to:

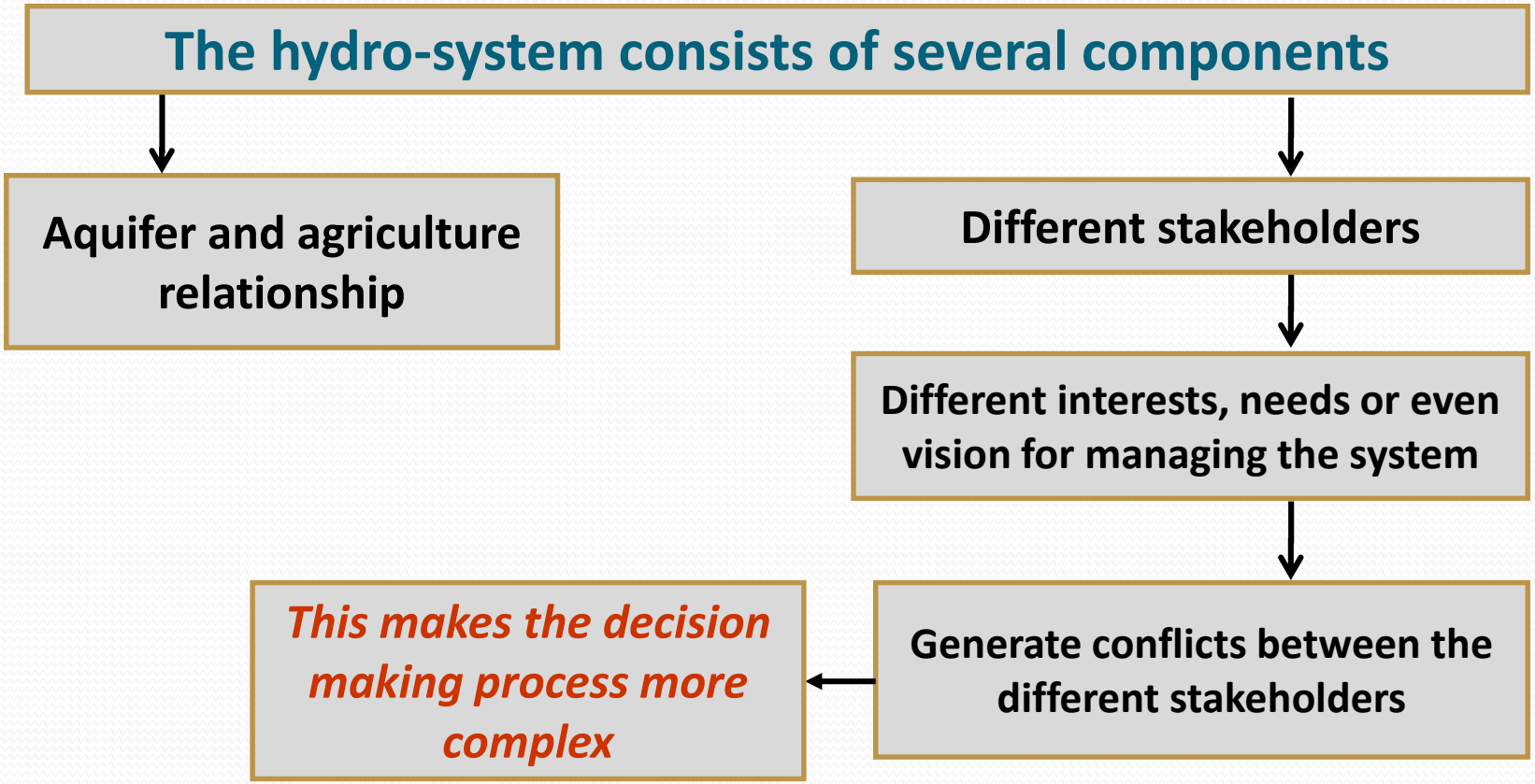
- Maintain GW aquifers.
- Increase water efficiency in irrigation.
- Increase agricultural productivity & income.

- Decline of groundwater levels and salinity intrusion.
- Some farms have become abandoned.

- On food production.
- Social consequences.

Introduction

Complexity of the situation



Introduction

A global solution is needed;

- The system need to be managed for the mean term and the long term
- Communications in both directions need to be improved:
  - Between relevant Decision makers
  - Between Decision makers and farmers

Objectives

- Introduce → a participatory process within the frame of IWRM (to support DMs in taking more informed decisions).
- Explain the dilemma (common-pool resources dilemma) with respect to the behaviors of the stakeholders, & identify if the participatory approach is accepted or rejected.
- Identify ways to improve the probability of a specific intervention to be implemented, & with what factor this intervention is more likely to be implemented.
- Identify if model approaches can be used to predict future scenarios in a changing environment.

Methodology

Framework for the Assessment and Modeling of Stakeholder Participation

Steps	Methods
1. Description of the problem	• Observation • Literature Review • Experts' Opinions
2. Data collection	Social Survey • Questionnaires • Interviews
3. Analysis	Statistical Analysis • Descriptive Statistics • Cross Tabulations
4. Modeling	• Discriminant Analysis (DA) • Bayesian Network (BN)

Methodology framework for human behavior and opinions in agriculture and water management for the Omani case, South Al Batinah

Methodology

Modeling with Bayesian Network

Used for mapping stakeholders' behaviors and to analyse the strength of a relationship between dependent and predictor variables.

A BN is a type of Decision Support System (DSS)

The basic idea of BNs is Probabilistic reasoning

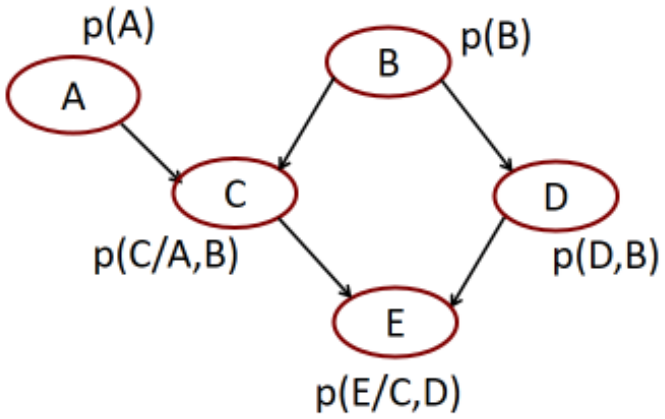
Assume the events are A and B respectively, than

"the probability of A given B"

$p(A|B)$

Rule for Conditional Probability:

$p(A|B)=p(B)p(A\cap B)$

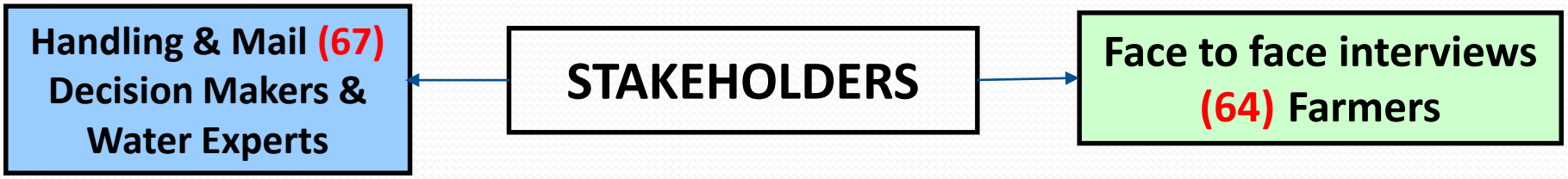


$p(A,B,C,D,E)= p(A)\ p(B)\ p(C/A,B)\ p(D,B)\ P(E/C,D)$

Focus on water quota & the evaluation of implementation potential

Results and Discussion

Overview of the Survey



General specifications of the management interventions (18 items)

- Focus on water demand side measures to reduce water consumption → water quotas, and subsidies
- Focus on water resources side measures to increase the availability of water → climate conditions ,artificial recharge units

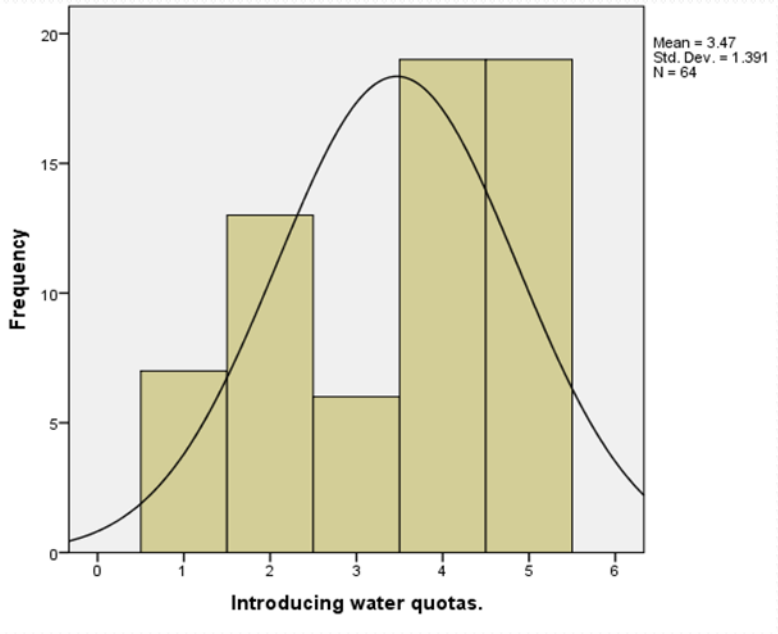
General Opinions of Farmers and DM's

Farmers → likely to the solutions of increasing water availability especially of good water quality, while DM's → likely to the management issues especially demand management.

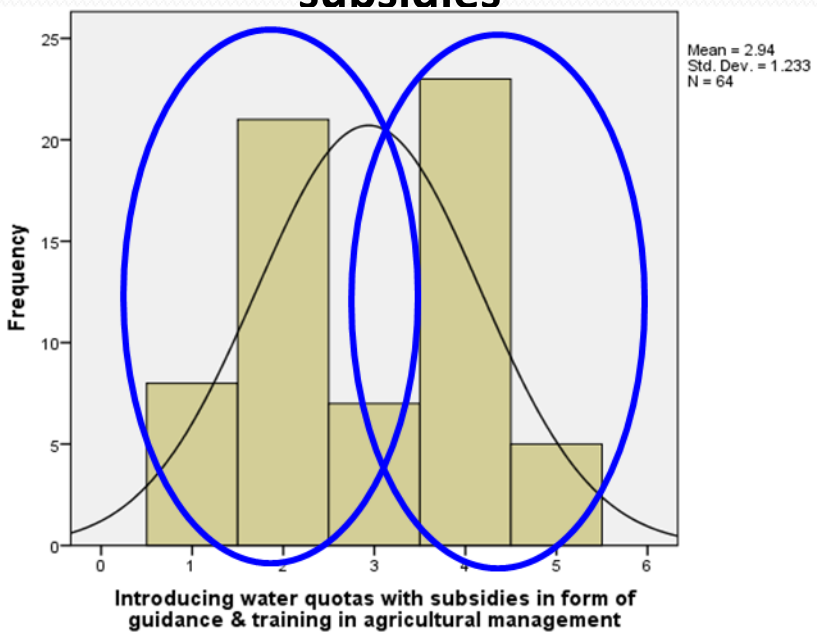
Results and Discussion

Drivers behind Opinions -Frequency Curves (Farmers)

Introducing water quotas



Introducing water quotas with subsidies



Score ranges between 1 for strongly agree and 5 for strongly disagree

% of farmers agreed & % of farmers rejected the idea of water quota with subsidies, is similar.

Cross-tabulation + DA are performed to identify the parameters which might be the reason behind.

Results and Discussion

Discriminant Analysis (DA)

List of Indicators

No.	Indicator	Type
1	Age (A)	A
2	Farm size (fd)	A
3	Area used for agriculture (fd)	A
4	Area used for commercial (fd)	A
5	Salinity range (µs/cm)	A
6	Educational level	C
7	Level of cooperation with water related organizations	C
8	Farm classification	C
9	Percentage of products sold	C

(A) continuous data and (C) categorical data, (fd) feddan

Used with mixed list of categorical and continuous data

Results and Discussion

Discriminant Analysis (DA)

The suggested discriminators by Discriminant Analysis

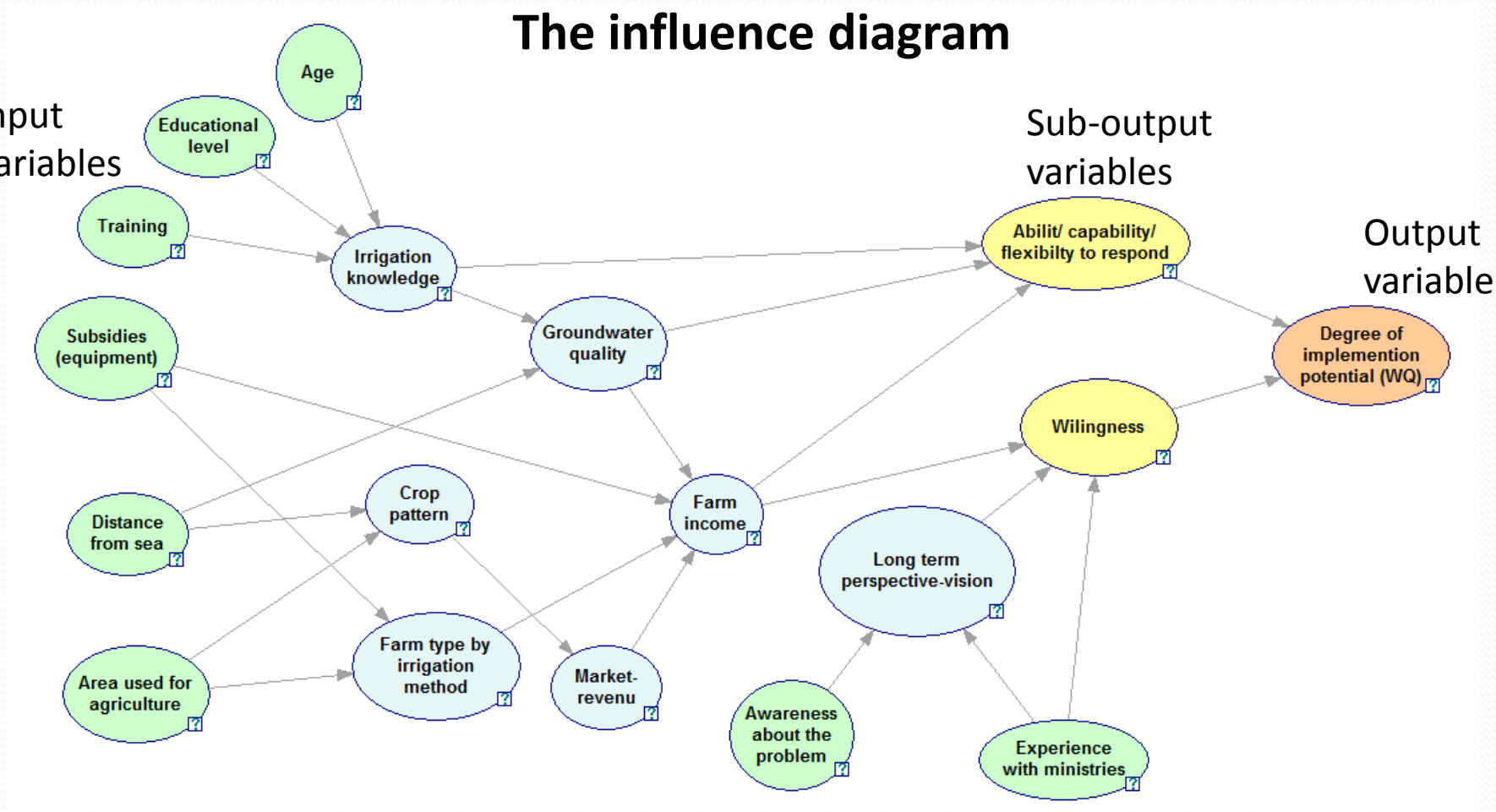
Analysing options	No. of samples	Suggested discriminators	Canonical correlation
Water quota			
Stepwise method	40	1. Salinity range	0.352
Independents together method	40	1. Level of cooperation with water Org. 2. Salinity range	0.516
Water quota with equipment			
Stepwise method	40	No variables are qualified for the analysis	--
Independents together method	40	1. Level of cooperation with water Org. 2. Area used for commercial 3. Farm size	0.448
Water quota with guidance & training			
Stepwise method	40	No variables are qualified for the analysis	--
Independents together method	40	1. Level of cooperation with water Org.	0.469

Focus on water quota & the evaluation of implementation potential

Results and Discussion

Modeling with Bayesain Network

The influence diagram

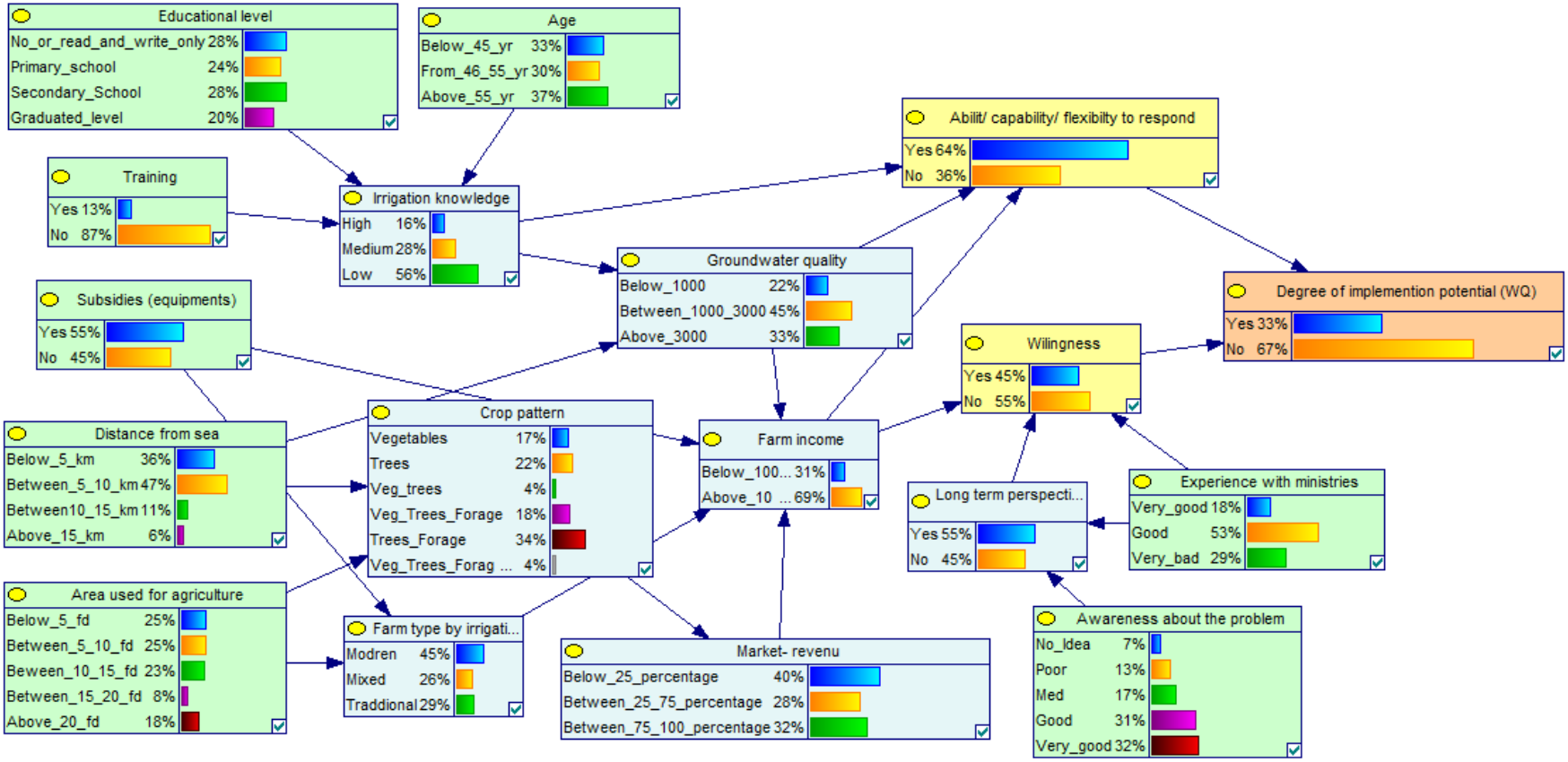


Manual step for determination of the variables and conditions

Results and Discussion

Modeling with Bayesain Network

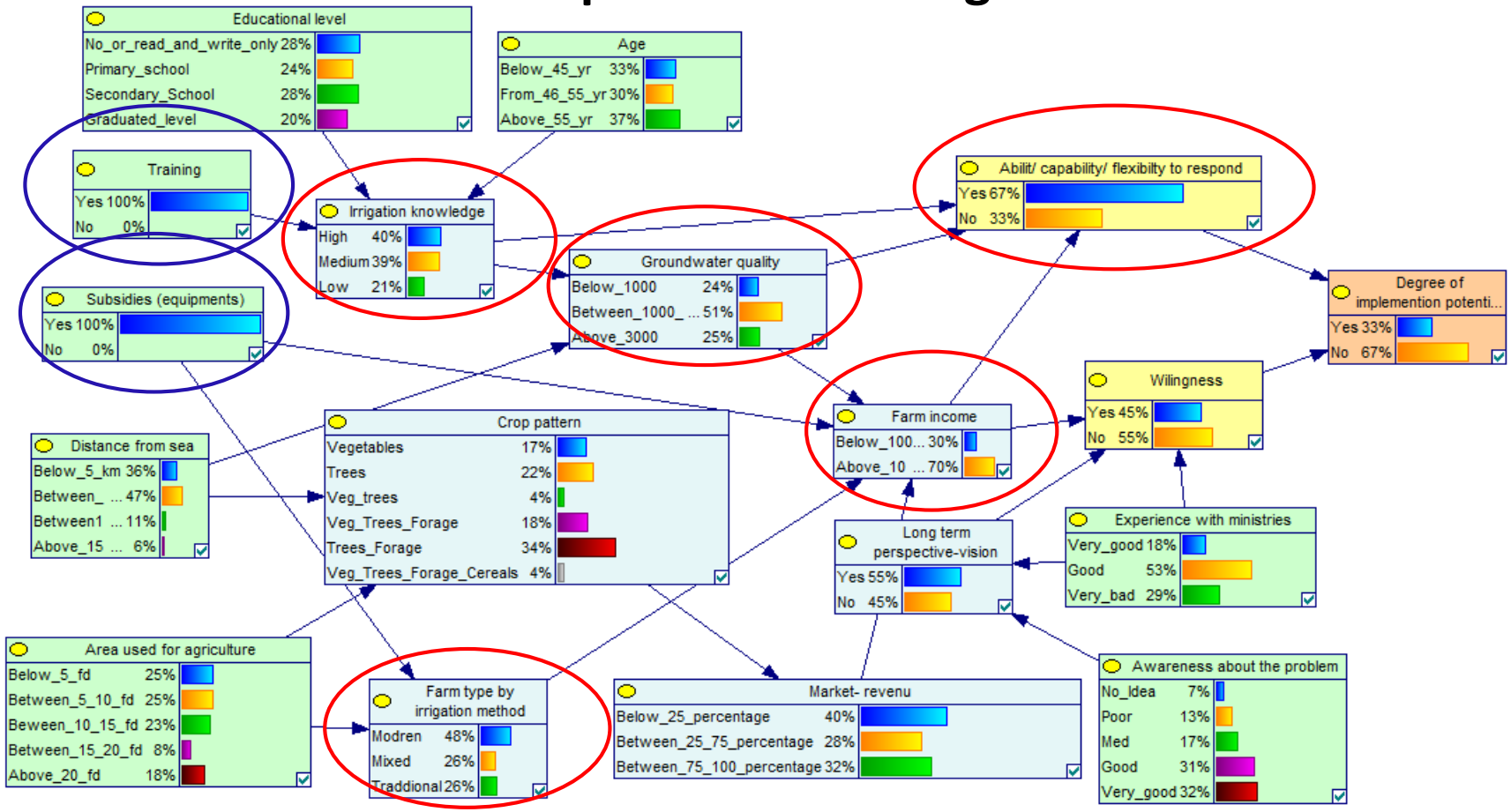
The structure of the BN (The focus issue is Implementation of water quotas)



Results and Discussion

Modeling with Bayesain Network

The impacts of “Training” and “Subsidies”



Results and Discussion

General results from the BN model :

- The hypothesis for most of the variables worked logically.
- Impacts of the input variables on the (WQ) implementation potential were limited.
- Some variables (e. g. subsidies from the government) –are related to the adoption of WQ.
- If the BN is too big, there are no much effects on the output

Suggestions to improve the BN model :

- Ordering the variables is very important (e.g. cause should come before the effect).
- The number of nodes and arcs should be minimal as much as possible. *It is good to have a higher number of samples and a simplified network.*

Summary of Results

- Need of improvement and implementing new management strategies is supported by all groups of stakeholders.
- The idea of the participatory approach is not rejected by the different groups of stakeholders.

Conclusions

- The study underlines the importance of a participatory approach with contributions from all relevant stakeholders in order to achieve a real IWRM implementation process.
- Water management strategies should not only focus on the technical means, but should also be directed to improve management practices and social behavior changes.
- A coordinated response is needed between relevant organization, farmers as well as the media to help this message become part of local understanding.
- Level of trust between users and decision makers has an impact on the level of acceptance of farmers regarding implementing a particular intervention.

Recommendations

- Management interventions should be also evaluated regarding economic and environmental criteria.
- Assess the impacts of the implemented measures. This should be done with the help of models.
- Persuading farmers by incentives and subsidies.
- Continued stakeholder feedback.

Thank you