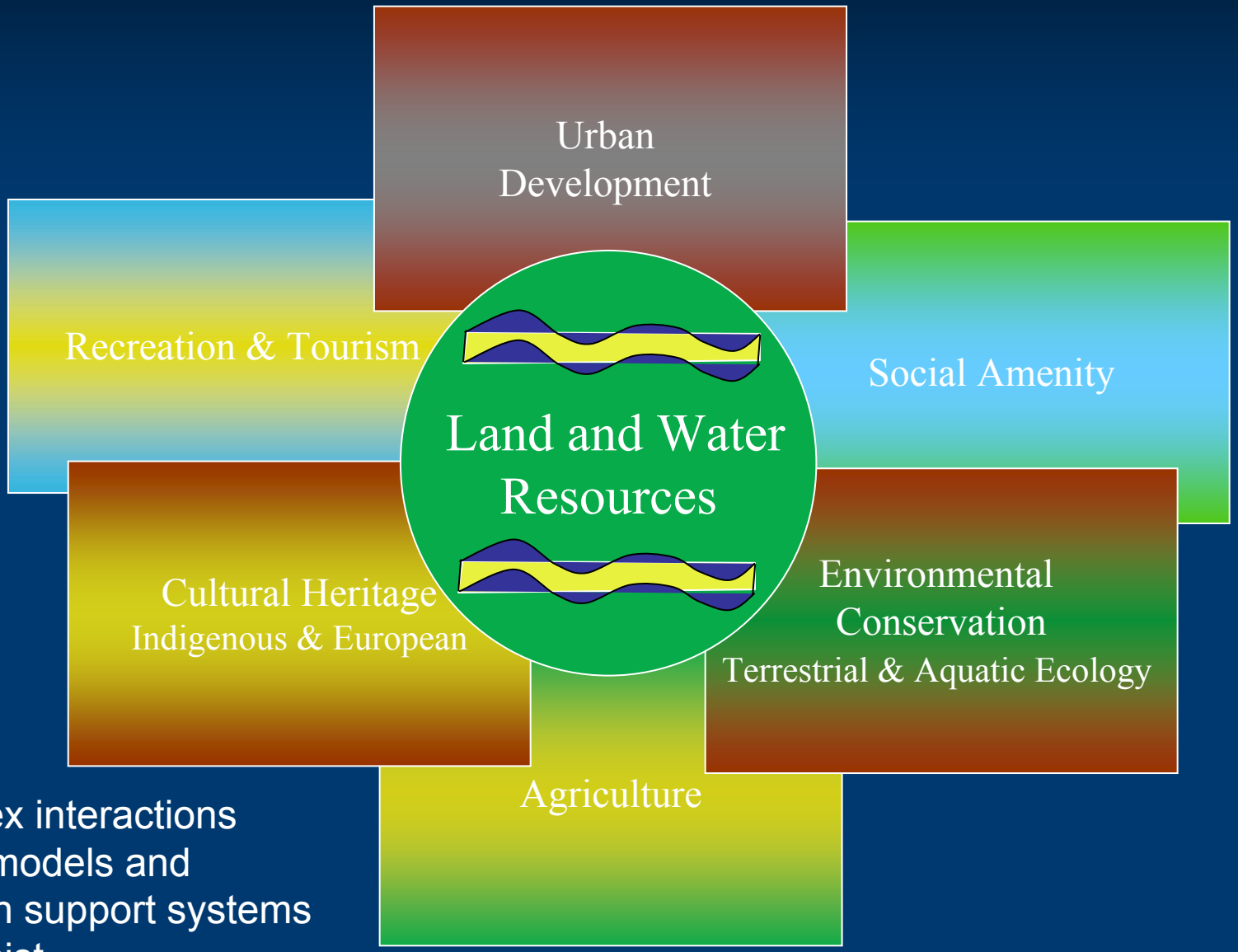
Introduction to Bayesian Decision Networks

Issues of NRM Sustainability



Complex interactions where models and decision support systems can assist

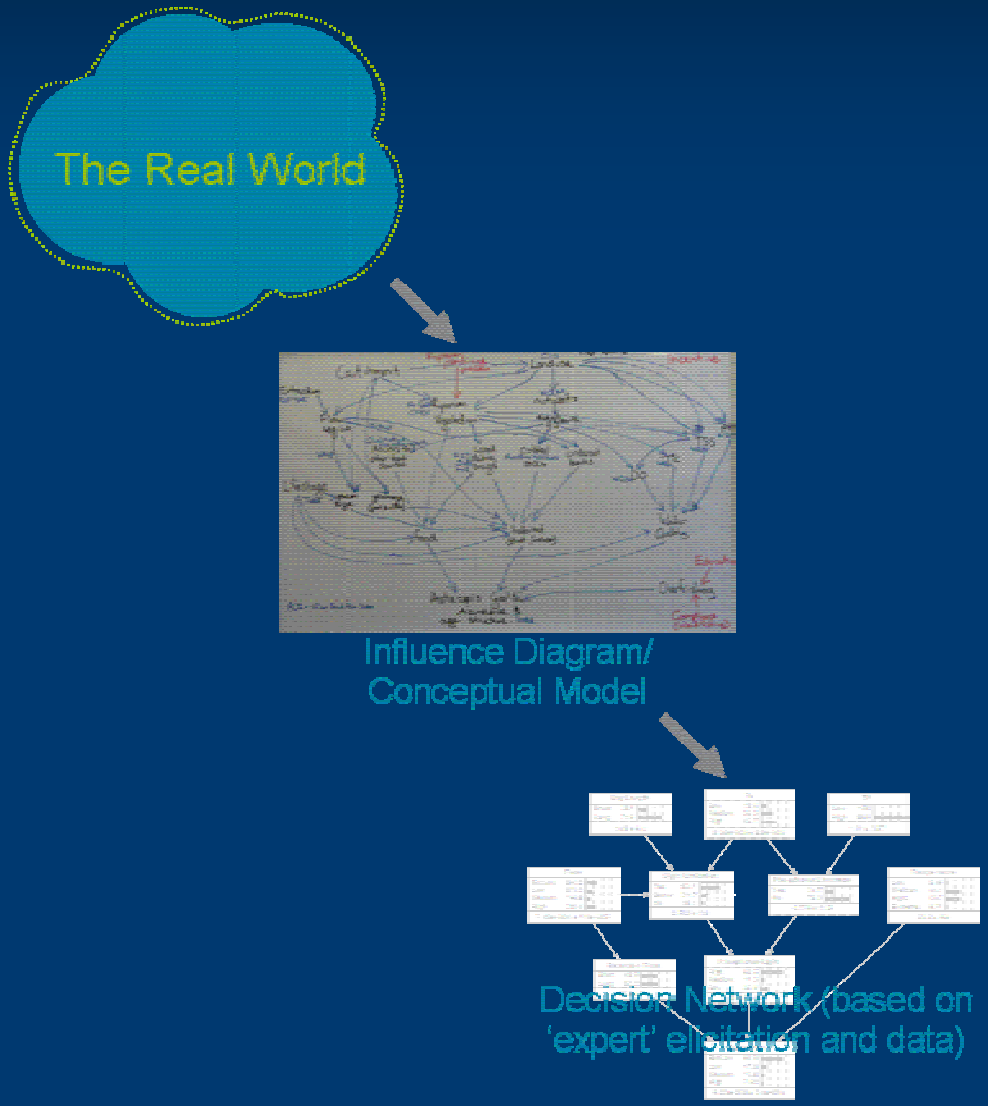
NRM Models

- In NRM, we need models that:
  - Inform decision making
  - Represent complex systems (i.e. multiple interacting variables)
  - Incorporate knowledge and data
  - Quantify uncertainties
  - Promote adaptive management
  - Scientifically robust

Integration Approaches

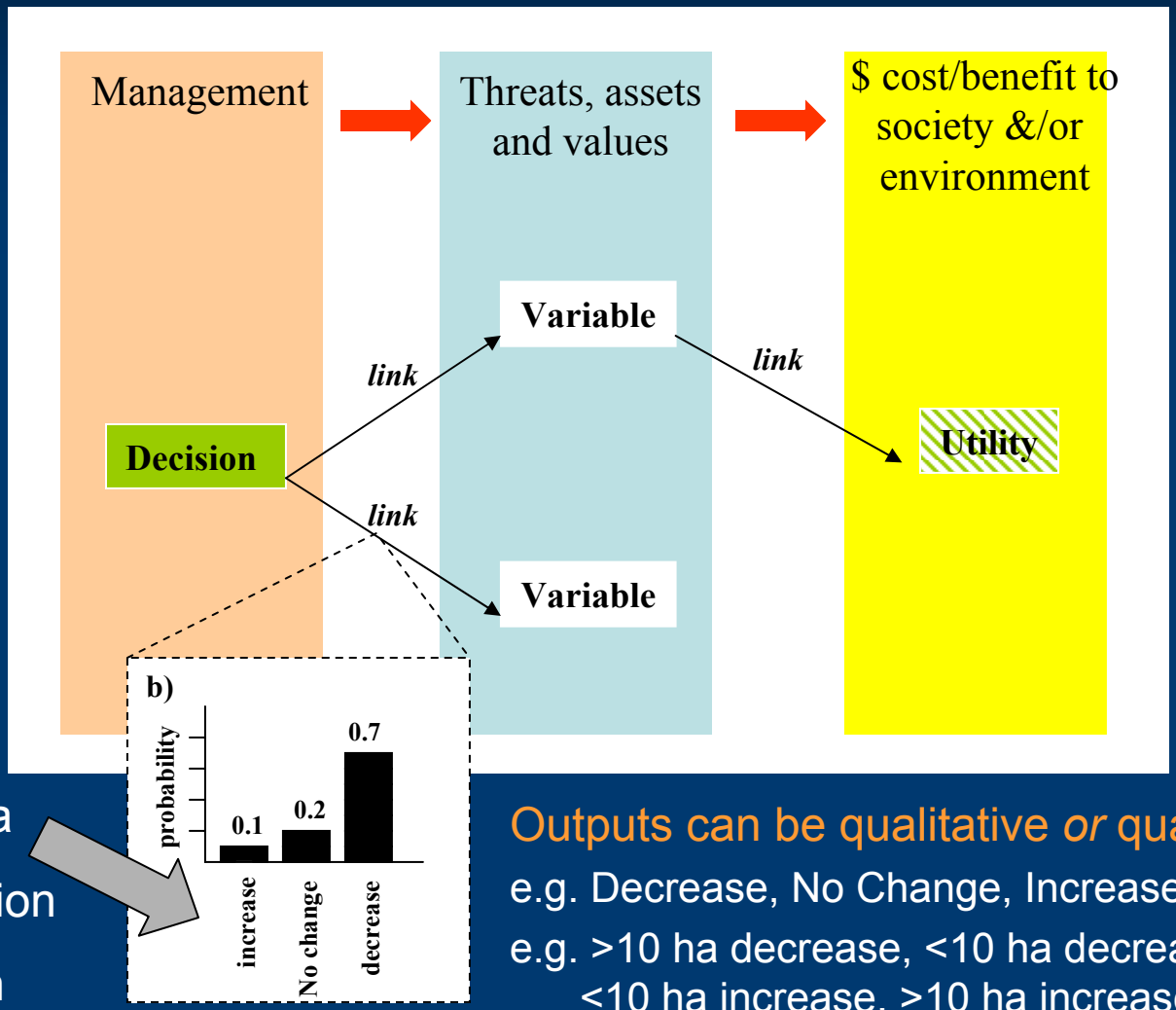
		System dynamics	Bayesian networks	Meta models	Coupled complex models	Agent based models	Expert systems
Model Purpose	Prediction		XXXX	XXXX	XXXX		XXXX
	Forecasting			XXXX	XXXX		XXXX
	Decision making	XXXX	XXXX	XXXX	XXXX		XXXX
	System understanding	XXXX			XXXX	XXXX	XXXX
	Social learning	XXXX			XXXX	XXXX	XXXX
Input Data Type	Qualitative and quantitative		XXXX				XXXX
	Quantitative only	XXXX		XXXX	XXXX	XXXX	
Focal Range	Focused and indepth				XXXX		
	General and broad	XXXX					
	Compromise			XXXX			XXXX
	Both		XXXX			XXXX	
Express uncertainty	Yes		XXXX				XXXX
	No	XXXX		XXXX	XXXX	XXXX	
Model Output	Individual					XXXX	
	Aggregated	XXXX	XXXX	XXXX	XXXX		XXXX

Building Bayesian (Decision) Networks (BNs)



Bayesian Decision Networks

Have 2 components: Structure and Probabilities



Observed data

Model simulation

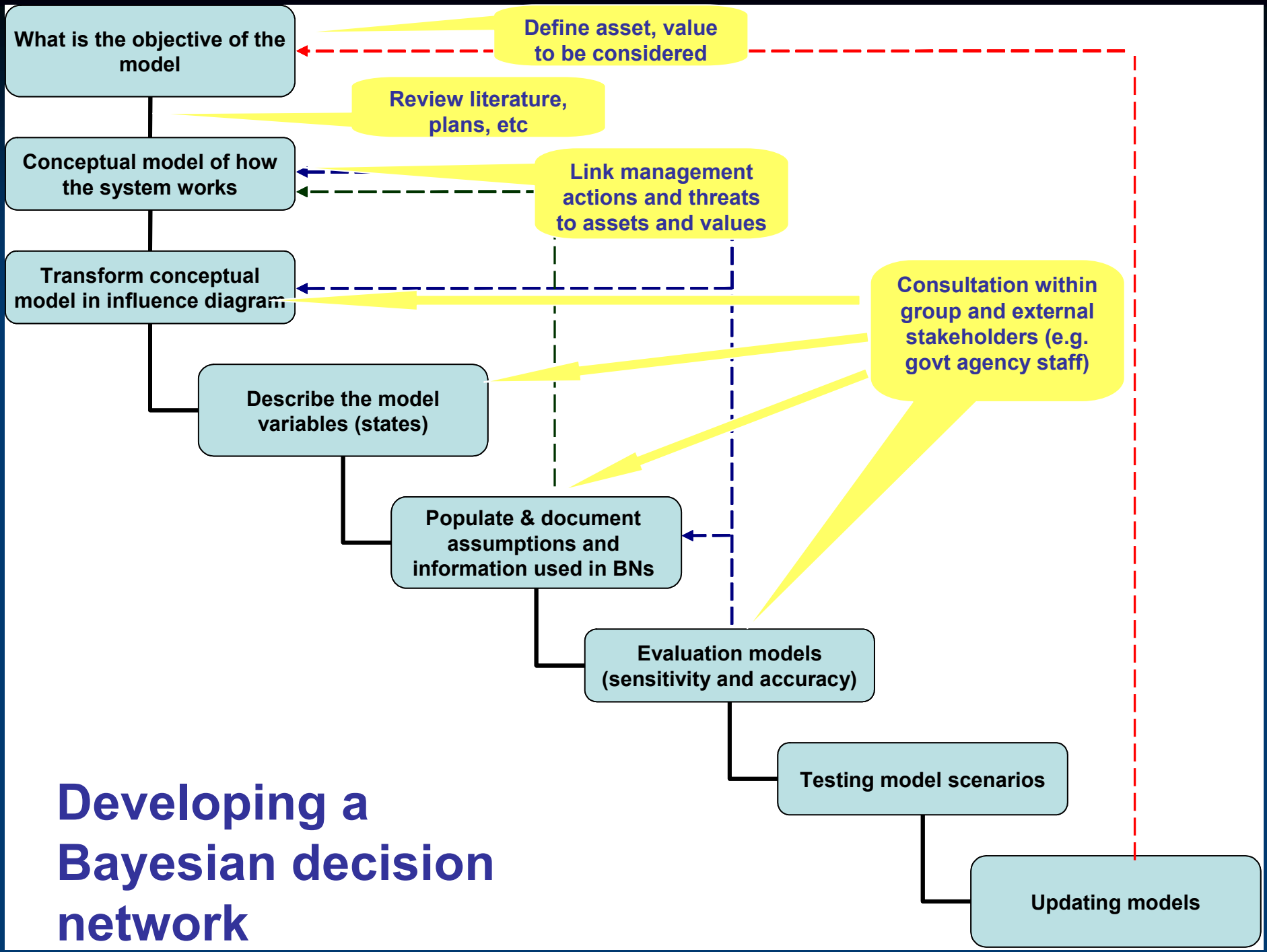
Expert opinion

Literature

Outputs can be qualitative *or* quantitative

e.g. Decrease, No Change, Increase

e.g. >10 ha decrease, <10 ha decrease, No change, <10 ha increase, >10 ha increase



Developing a Bayesian decision network

Example BDN: Fish management

- Define question, including spatial and temporal scale.
  - *“Which actions are most likely to enable populations of the ‘fish’ populations to reach the target population?”*

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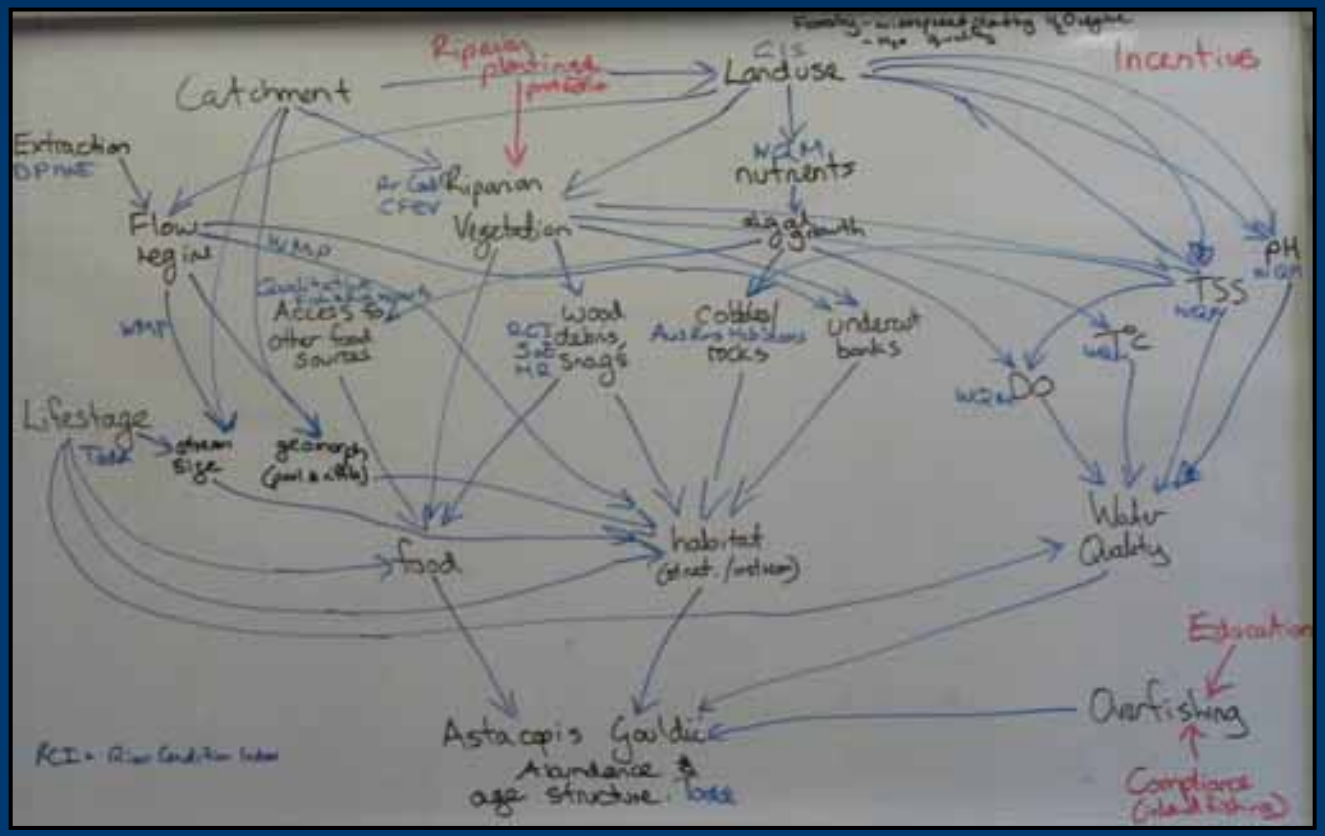
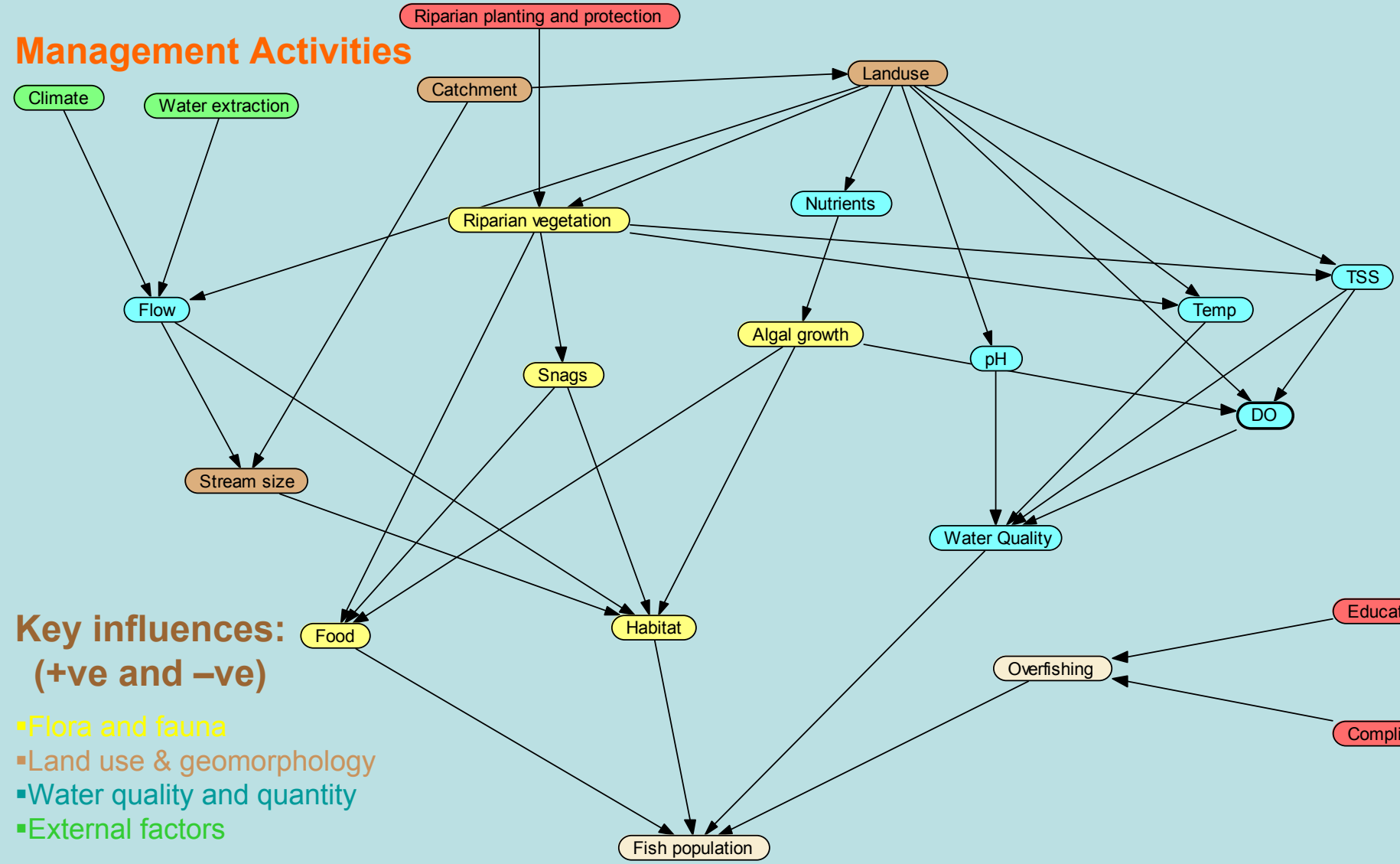
White boarding an Influence Diagram

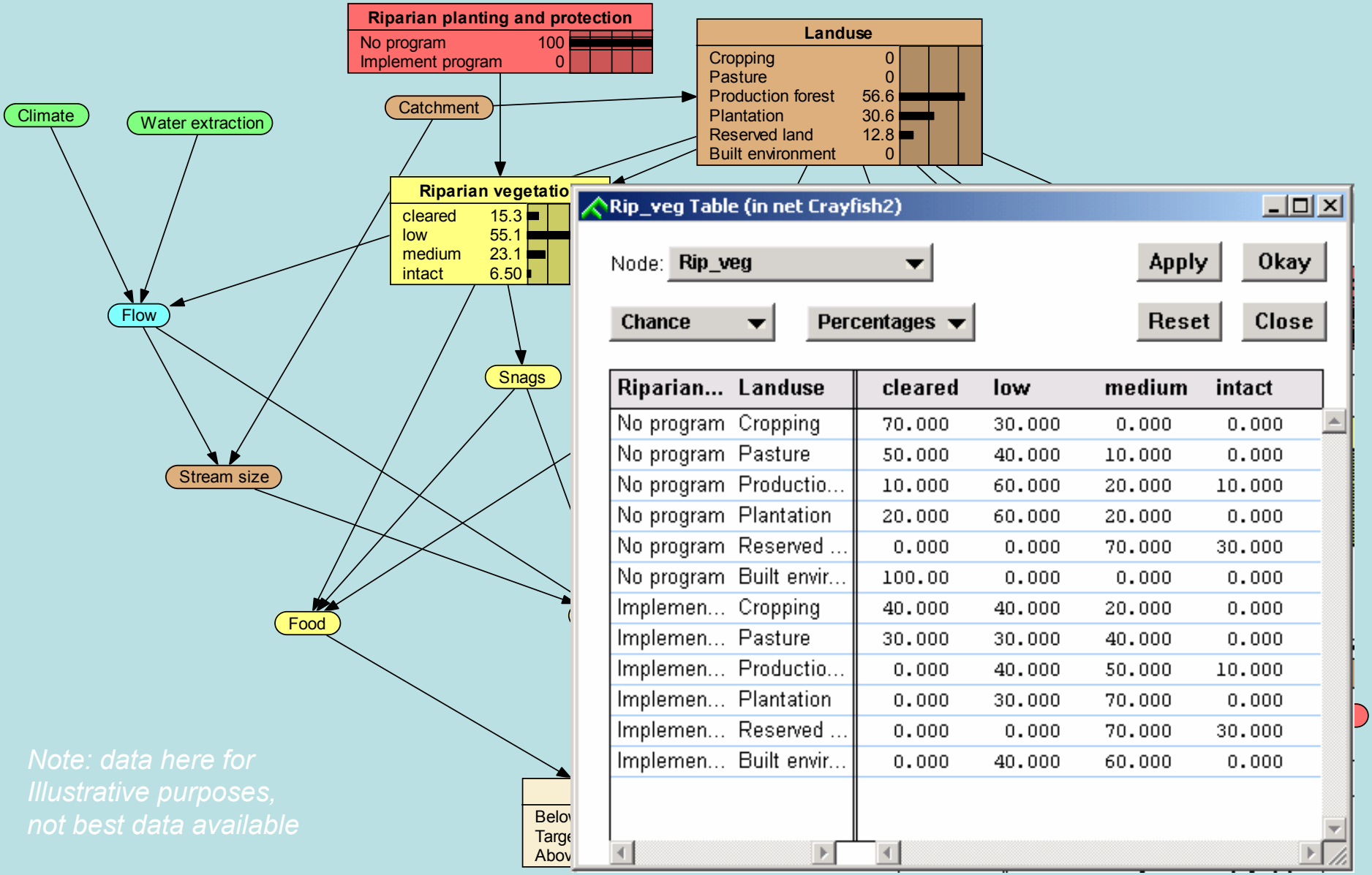


Developing influence diagram



Key focus

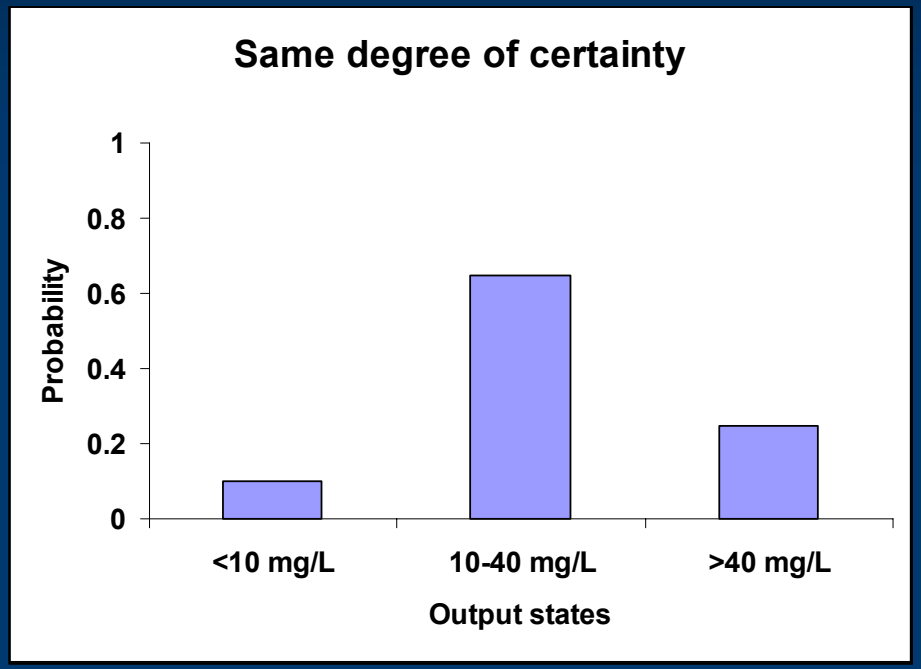
Adding states and data



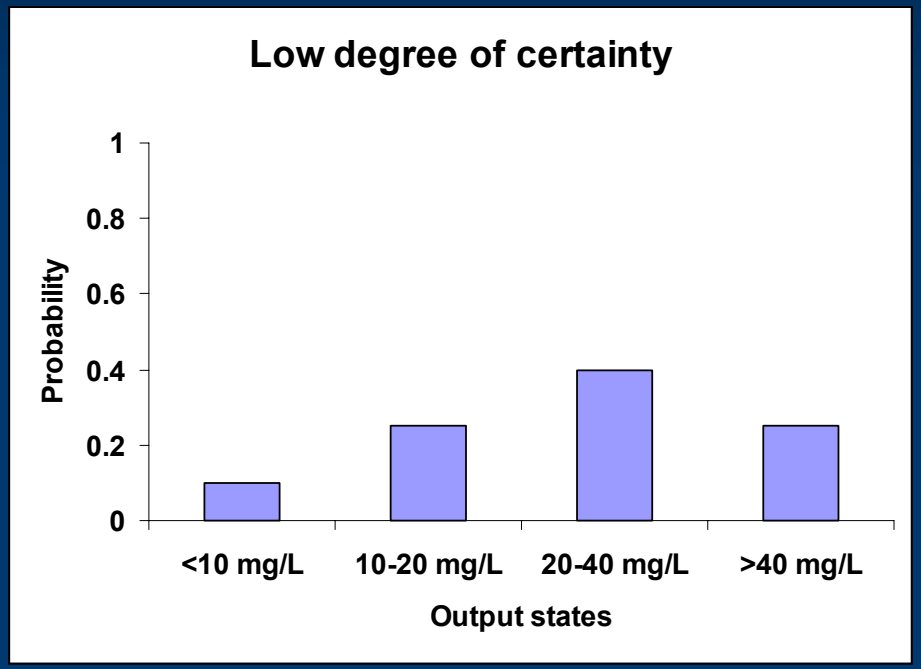
Riparian...	Landuse	cleared	low	medium	intact
No program	Cropping	70.000	30.000	0.000	0.000
No program	Pasture	50.000	40.000	10.000	0.000
No program	Productio...	10.000	60.000	20.000	10.000
No program	Plantation	20.000	60.000	20.000	0.000
No program	Reserved ...	0.000	0.000	70.000	30.000
No program	Built envir...	100.00	0.000	0.000	0.000
Implemen...	Cropping	40.000	40.000	20.000	0.000
Implemen...	Pasture	30.000	30.000	40.000	0.000
Implemen...	Productio...	0.000	40.000	50.000	10.000
Implemen...	Plantation	0.000	30.000	70.000	0.000
Implemen...	Reserved ...	0.000	0.000	70.000	30.000
Implemen...	Built envir...	0.000	40.000	60.000	0.000

Note: data here for Illustrative purposes, not best data available

Reflection of Uncertainty



Probability concentrated in 1 or 2 output states



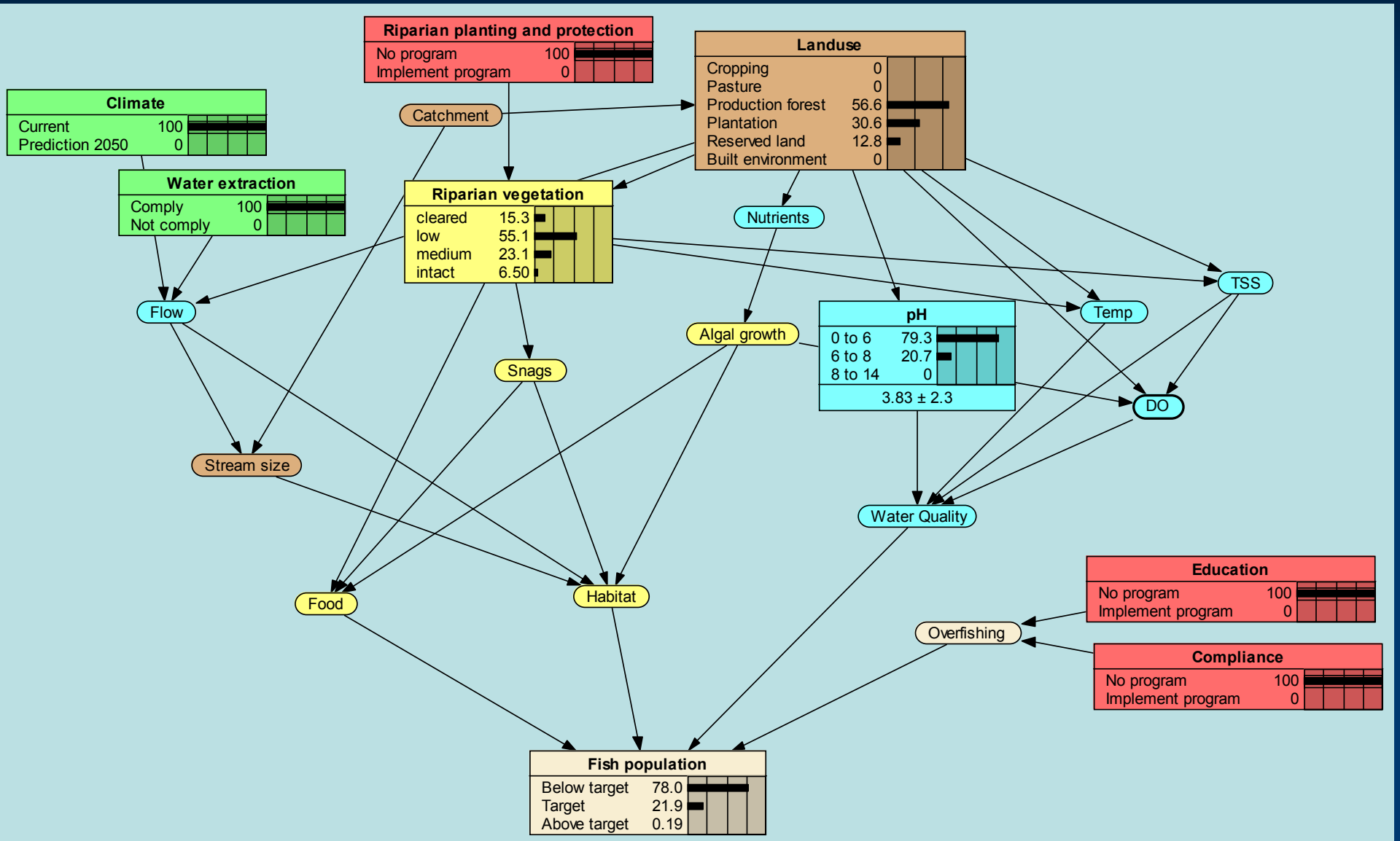
Wide distribution in many output states

NOTE: If states are coarser, there is a higher perceived certainty in the output

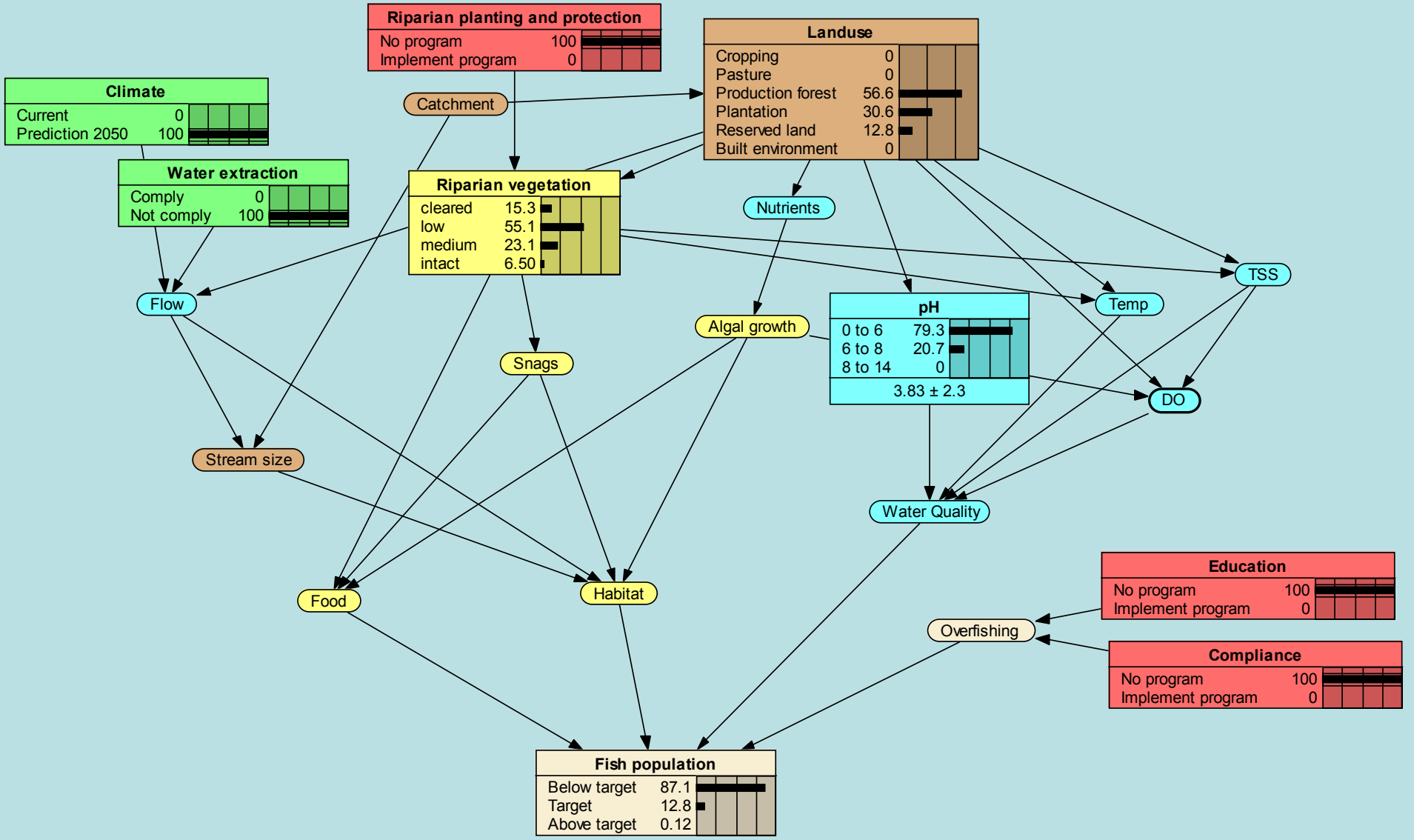
BDNs and Scenarios

- Scenarios – explore ‘What if?’
- Test management or system changes
  - Examine relative system response (change of probabilities) while accounting for predictive uncertainties
- Therefore can assist in planning and investment decisions

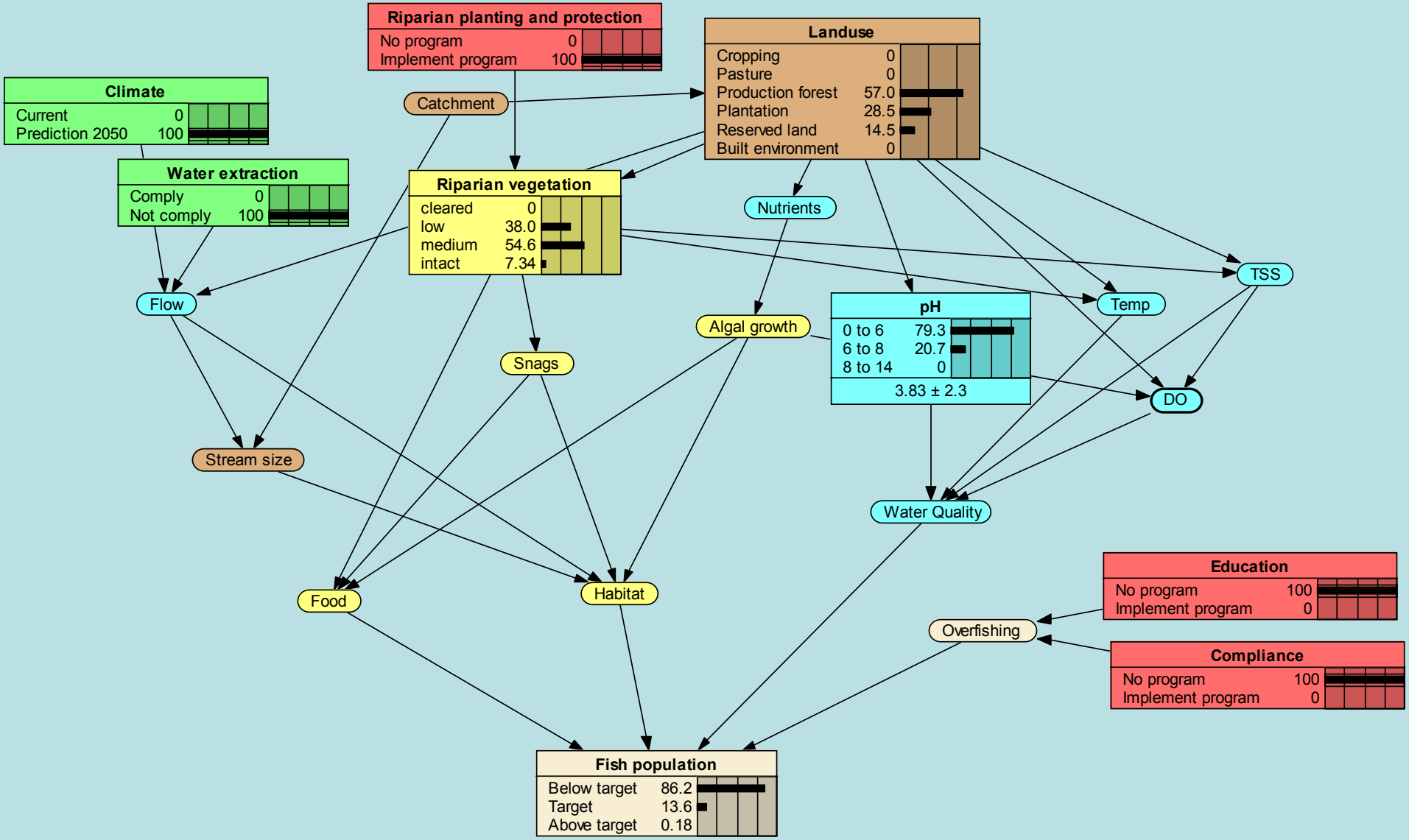
Decision Support



Decision Support



Decision Support



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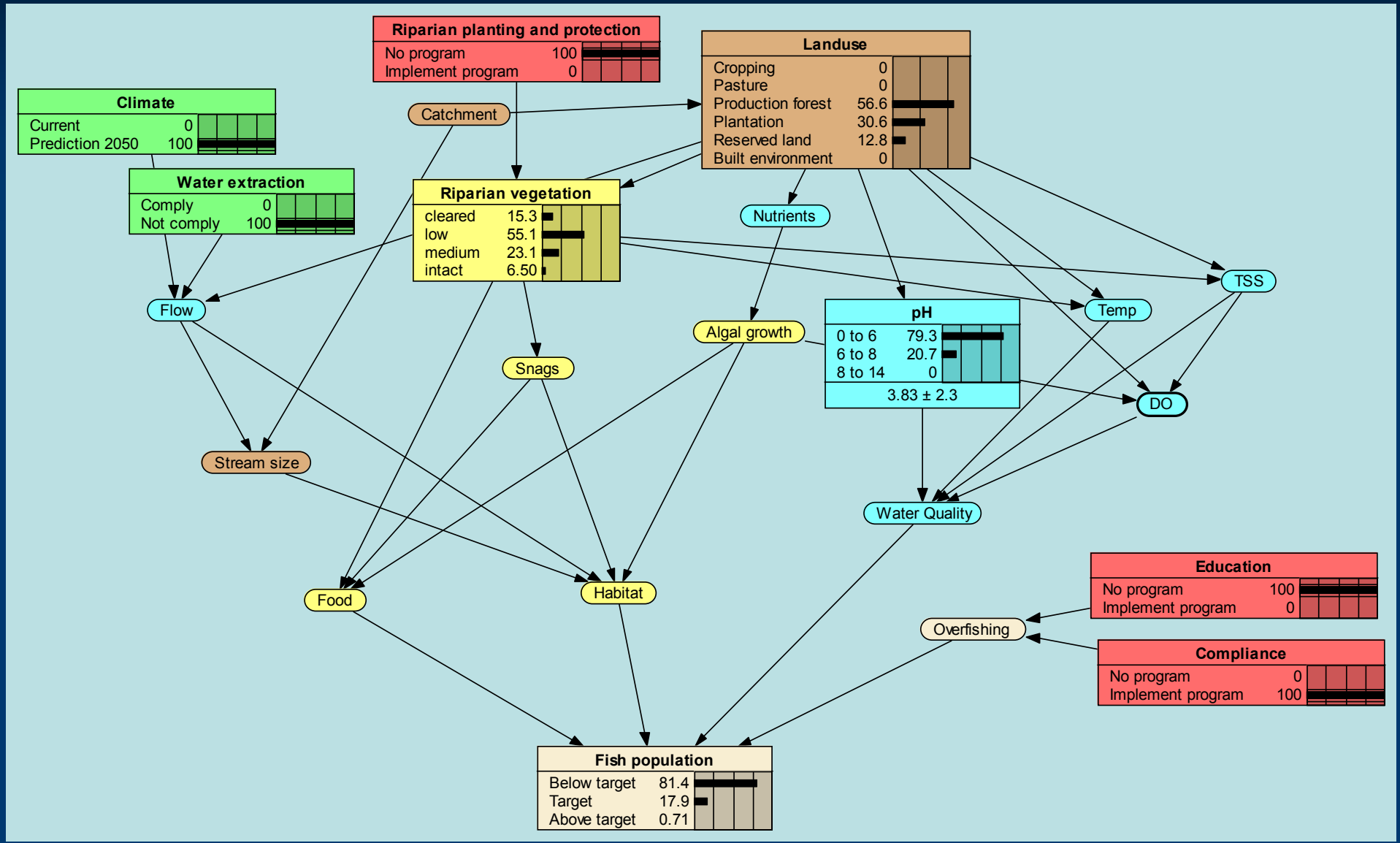
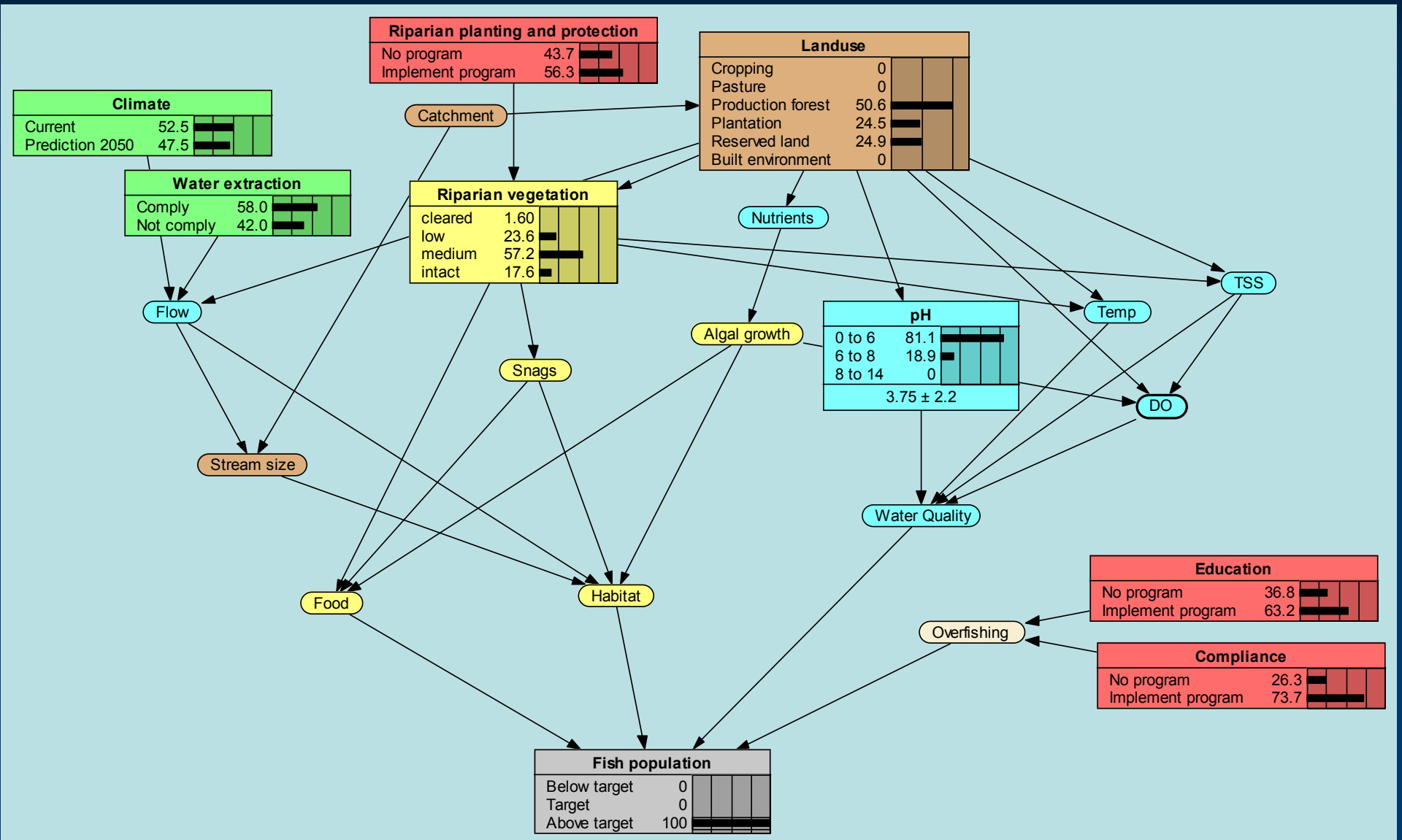
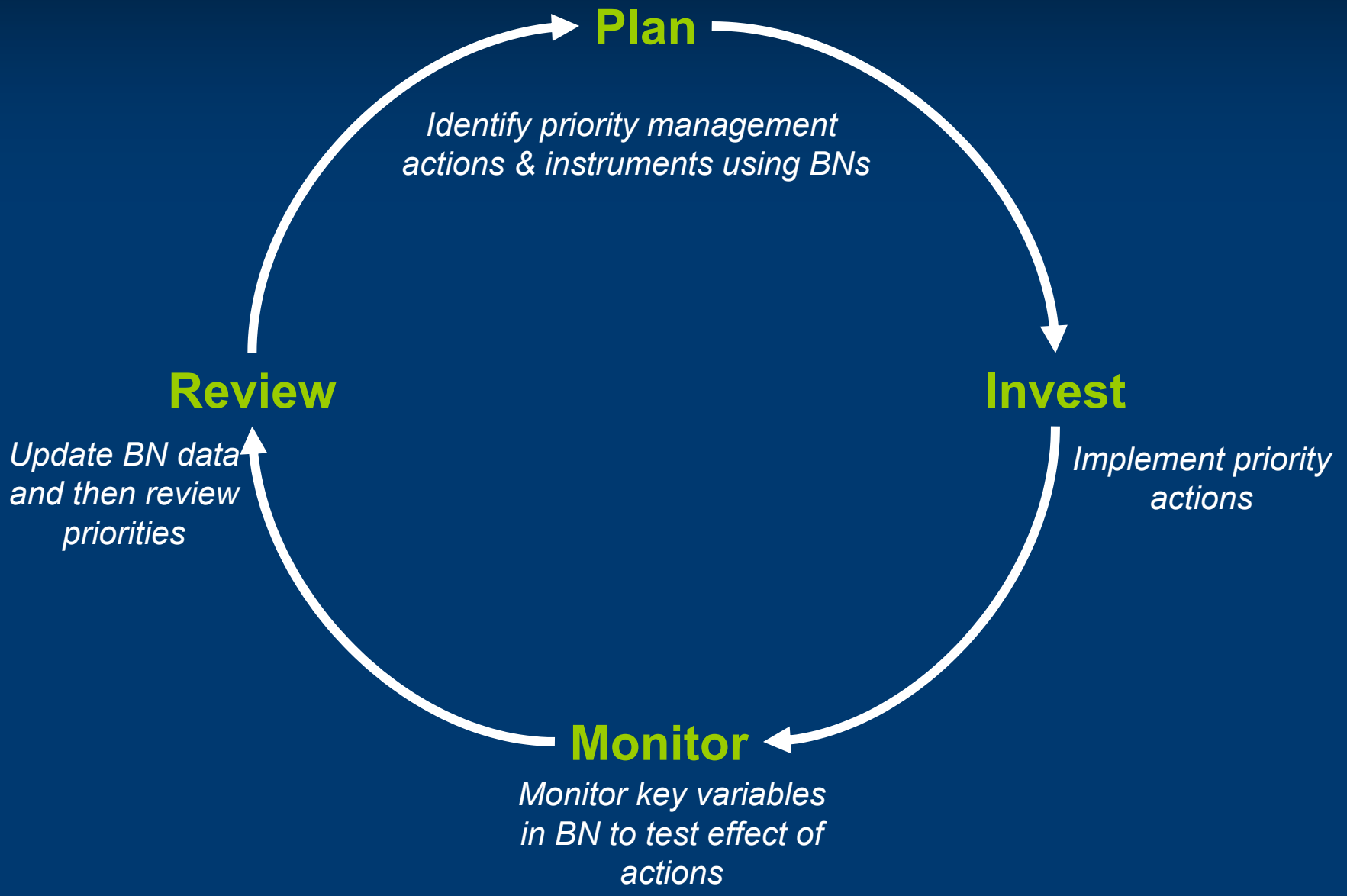
Decision Support



Decision Support



BNs and Adapative Management



Bayesian Network Strengths

- Relatively easy to represent complex systems
- Development process engages multiple people/groups (not an individual activity), and promotes systems learning
- Take into account uncertainties
- Can be used to identify key knowledge gaps and guide data collection
- Models iteratively updated (adaptive management)
- Can document current assumptions used for making decisions

Bayesian Network Strengths

- Integrate across disciplines
  - Hydrology, water quality, ecology
  - Economics, social, environmental

- Integrate different information sources to utilise the best information available
  - Qualitative: Expert assessments,
  - Quantitative: monitoring data, simulation models, research data.

Utilising Available Information

- We still make decisions when knowledge is poor
  - Capture assumptions and embed them in a framework where these can be tested
- Can test the sensitivity of assumptions
- Once assumptions are defined within the framework, management decisions are repeatable
- Increases transparency of management decisions

Define Model Scope

- Define model objective (what is the question?)
- Define model scales (what are the bounds?)

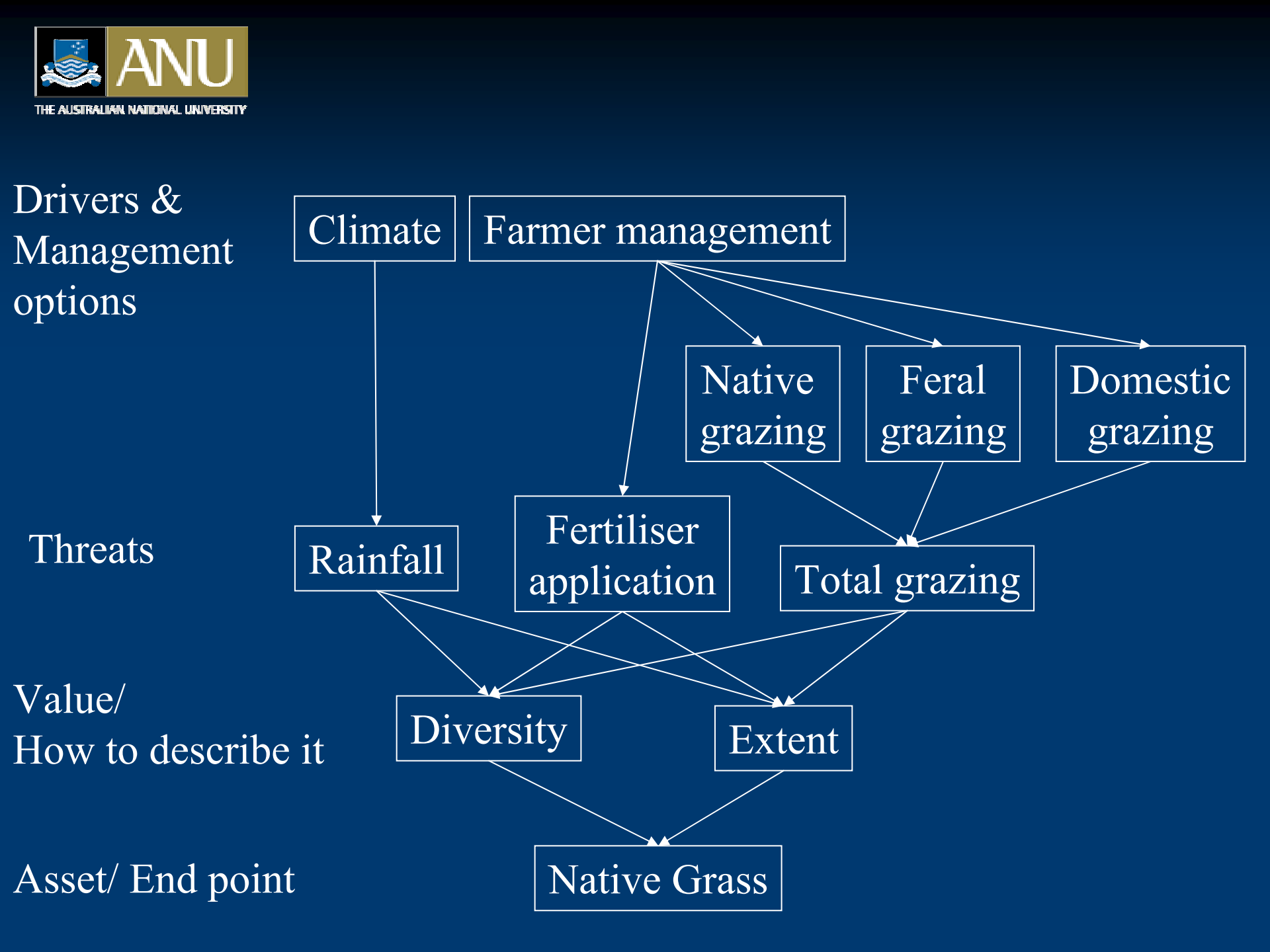
  Space (catchment specific) and Time
- Important points:
  - More complex model: ↑ parameters,↑ level of uncertainty (more parameters need to be estimated)
  - Matter of balance: holistic (general understanding) vs. reductionalist (fine detail)
    - This depends on your objective
  - BNs are not bound by lack of data and knowledge BUT the quality of your model is.

White board example:

- Question:

  How will native grasses in agricultural lands be impacted upon by climate into the long-term future (30 years)?

- Asset/End point = Native grasses
- Values/How do we describe it? diversity, extent…
- Threats? fertiliser, grazing,…..
- Drivers/ Management actions? farmer management


Drivers & Management options
Climate
Farmer management
Native grazing
Feral grazing
Domestic grazing
Threats
Rainfall
Fertiliser application
Total grazing
Value/ How to describe it
Diversity
Extent
Asset/ End point
Native Grass