Modelling and Integration for SDG-Oriented Planning in the Developing World

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Characteristics of Sustainable Development Challenges in the Developing World

- Dual formal and informal systems.
- Rapid urbanisation (without industrialisation).
- High rates of change and uncertainty: ‘glocal’ interactions play a key role.
- Poverty, inequality, precarious households.
- Infrastructure deficits: a limitation and opportunity.
- Spending and finance gaps at local levels.
- Lack of capacity for planning at local levels (especially integrated planning).

Decision Support and Modelling Challenges in Developing World Contexts

- Lack or absence of adequate, timely data.
- Often, only expert opinion and judgement available to work with.
- Lack of institutional capacity, skills and expertise to support detailed modelling.
- Lack of internet access and computing power.
- Conflicting agenda’s and interests drive development agendas.
- Fragmentation: Sectors, government departments, local authorities work in silo’s.

Summary:

- Both sustainable development challenges, as well as modelling them – especially in developing world contexts – are *complex* systems challenges.
- Swimming in an ocean versus swimming in a pool.

Complexity-Based Modelling of Transitions to SD

- Applying complexity theory to four broad theories of transitions to sustainability:
  - Decoupling theory.
  - Resilience theory.
  - Multi-level perspective on transitions to SD.
  - Behavioural change theory.

*Peter, C. and M. Swilling: Linking Complexity and Sustainability Theories: Implications for Modelling Sustainability Transitions; *Sustainability*, 6, pp. 1594-1622, 2014.

Complexity-Based Modelling of Transitions to SD

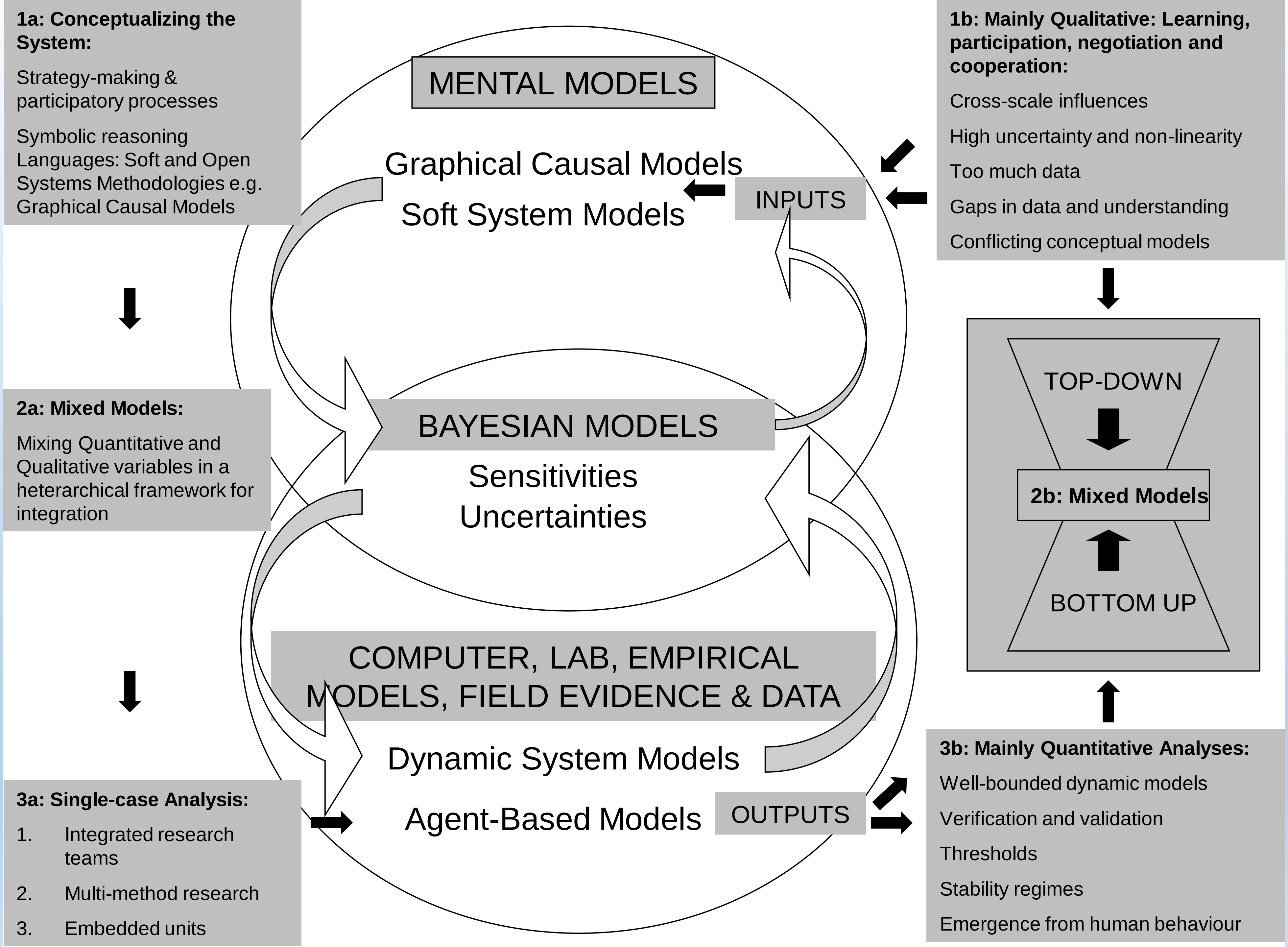
- The basis of the modelling (and planning) process should be (Peter and Swilling, 2014):
  - Probabilistic and adaptive:
    - Accommodate multiple possible futures (e.g. scenarios), and
    - System configurations (adaptive capacity, degeneracy, redundancy).
  - Integrative:
    - Cross-sector and cross-scale, where relevant.
    - Can accommodate quantitative and qualitative inputs.
  - Inclusive:
    - Inclusivity informs integration – encourages shared understanding.
    - Determining actions through shared understanding of system (and priorities, conflicts, etc.).
    - Dealing with undecidability – shared understanding of what generates undecidability can inform discussions regarding potential trade-offs, etc.
    - Adaptive capacity – boosted through inclusivity.
    - Creative capacity – boosted through inclusivity.

Soft and Hard Systems Modelling

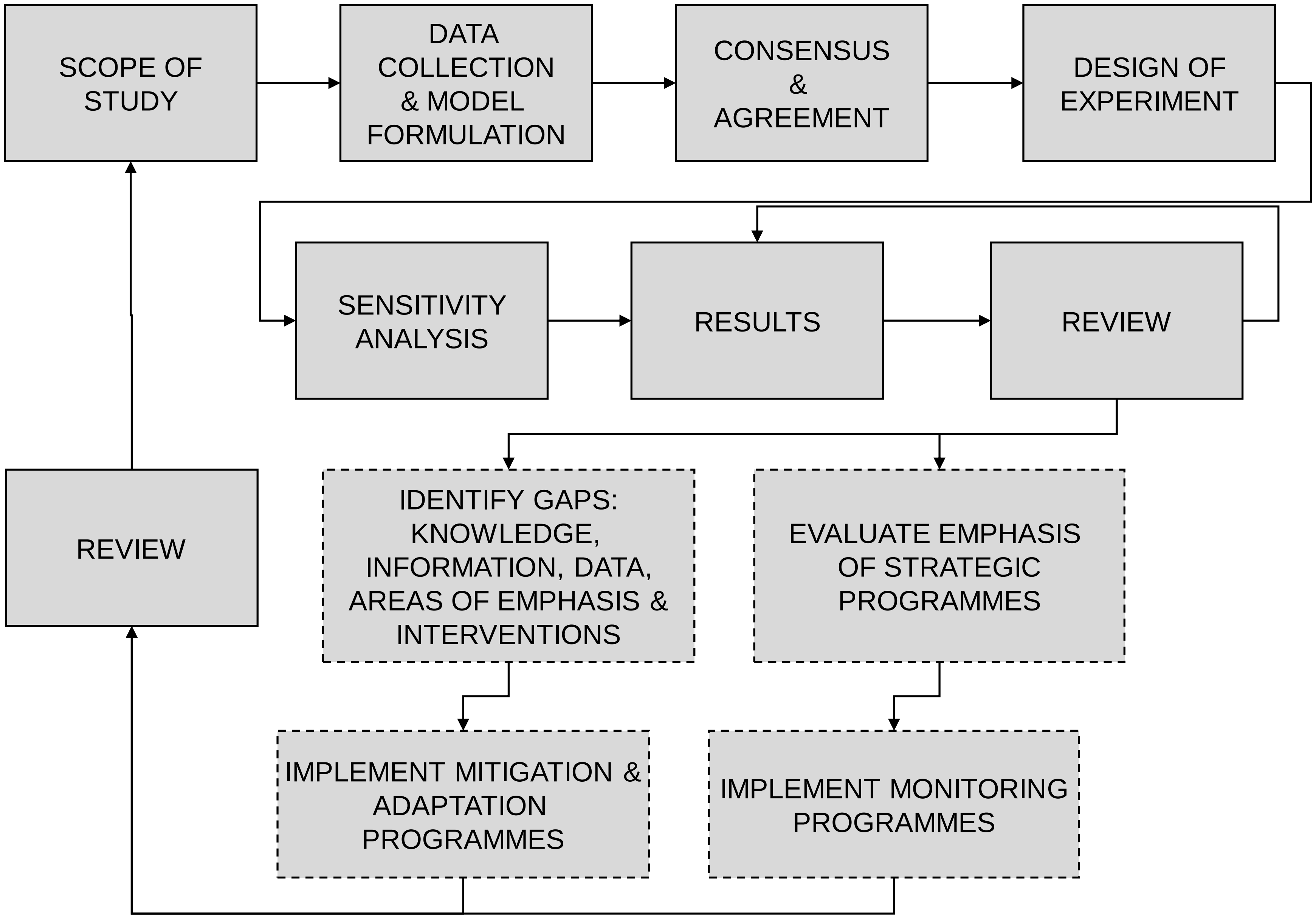
- Two broad levels of integration:
  - Soft: mix of qualitative and quantitative data and methods used in contexts where uncertainty about the system is greater and integration criteria are less well understood.
    - Soft Systems Modelling:
      - Causal loop diagrams.
      - Graphical causal models (GCMs), topic maps, decision trees, etc.
      - Bayesian networks (BNs): can mix quantitative and qualitative information.
  - Hard: mainly quantitative and numerical methods used in contexts where there is greater certainty about the system and integration criteria are better understood.
    - Systems dynamics modelling (SD) and agent-based SD.
      - Sector models (e.g. economic, agricultural, energy, water, etc.).
      - Spatial and system models (e.g. hydrological, land-use, spatio-temporal vegetation change, climate change, etc.).

Soft and Hard Systems Modelling

- Key Challenge: Linking soft and hard systems modelling efforts is critical for adaptive management of sustainable development efforts.
- This is because development is an iterative process of intervening, monitoring and measuring, and adapting plans as they are implemented i.e. we are dealing with a complex, adaptive system.
- Usually conducted within the mind(s) of a modelling expert or team of modelling experts – hampers full participation in adaptive management processes.


1a: Conceptualizing the System:
Strategy-making & participatory processes
Symbolic reasoning Languages: Soft and Open Systems Methodologies e.g. Graphical Causal Models
2a: Mixed Models:
Mixing Quantitative and Qualitative variables in a heterarchical framework for integration
3a: Single-case Analysis:
1. Integrated research teams
2. Multi-method research
3. Embedded units
MENTAL MODELS
Graphical Causal Models
Soft System Models
INPUTS
BAYESIAN MODELS
Sensitivities
Uncertainties
COMPUTER, LAB, EMPIRICAL MODELS, FIELD EVIDENCE & DATA
Dynamic System Models
Agent-Based Models
OUTPUTS
1b: Mainly Qualitative: Learning, participation, negotiation and cooperation:
Cross-scale influences
High uncertainty and non-linearity
Too much data
Gaps in data and understanding
Conflicting conceptual models
TOP-DOWN
2b: Mixed Models
BOTTOM UP
3b: Mainly Quantitative Analyses:
Well-bounded dynamic models
Verification and validation
Thresholds
Stability regimes
Emergence from human behaviour

ADAPTIVE MANAGEMENT DECISION SUPPORT PROCESS



Bringing Soft and Hard Systems Modelling Efforts Together: A More Powerful Approach

- Why Bayesian Networks as Integrators:
  - Probabilistic: non-linearity, forward and backward propagation.
  - Conditional causality: hypotheses testing i.e. for interventions.
  - Mix of quantitative and qualitative data/information; even subject matter expert opinion.
  - Inclusivity: easy to understand by non-scientists.
  - Cross-scale: supports modelling at nested scales i.e. vertical integration.
  - Cross-sector: i.e. horizontal integration.
  - Adaptable and modular – can support adaptive management programmes.
- Hence can manage integration between soft and hard modelling efforts better (i.e. more trace-ably, iteratively and reliably).

CAUSAL LOOP MODEL

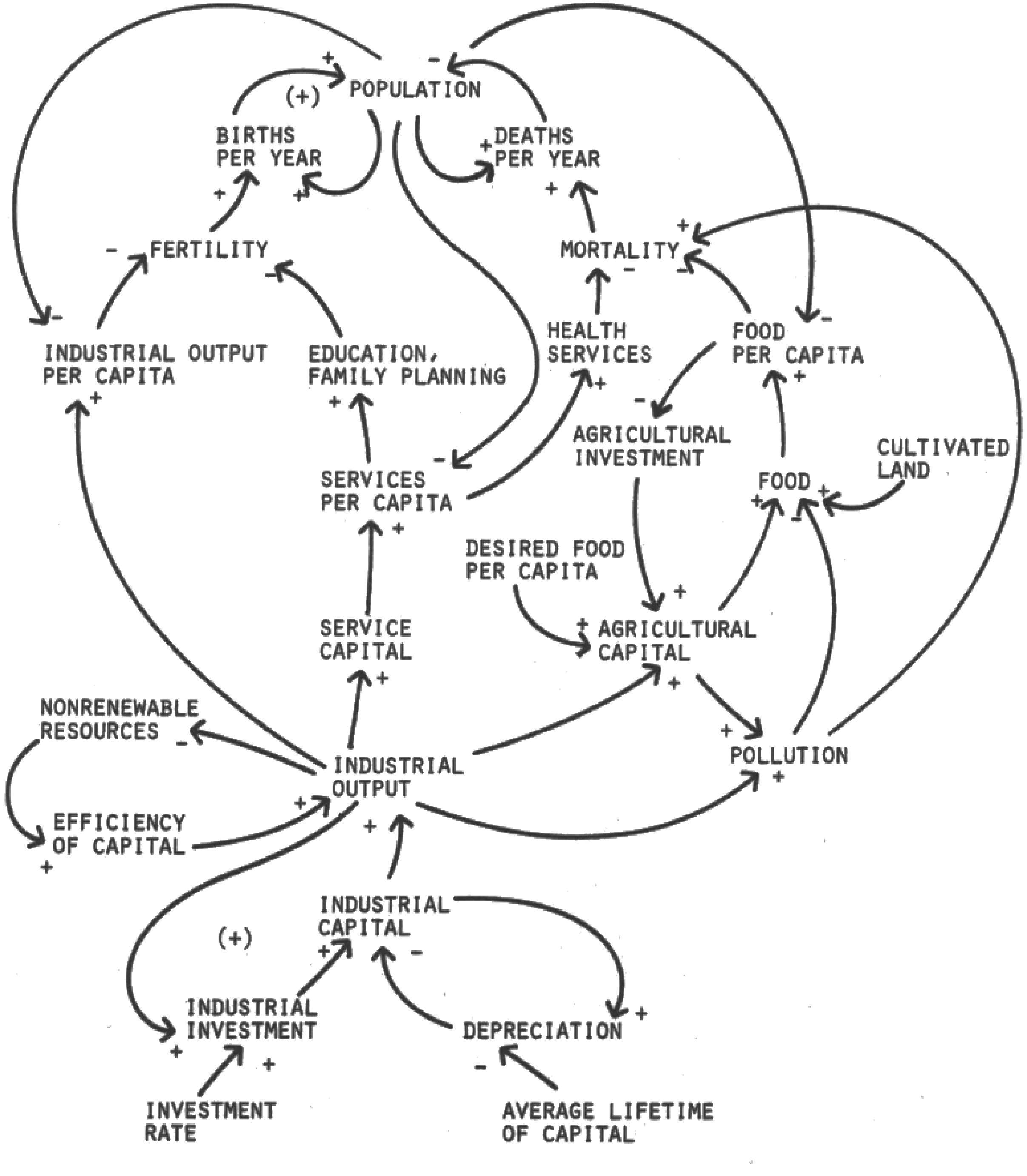
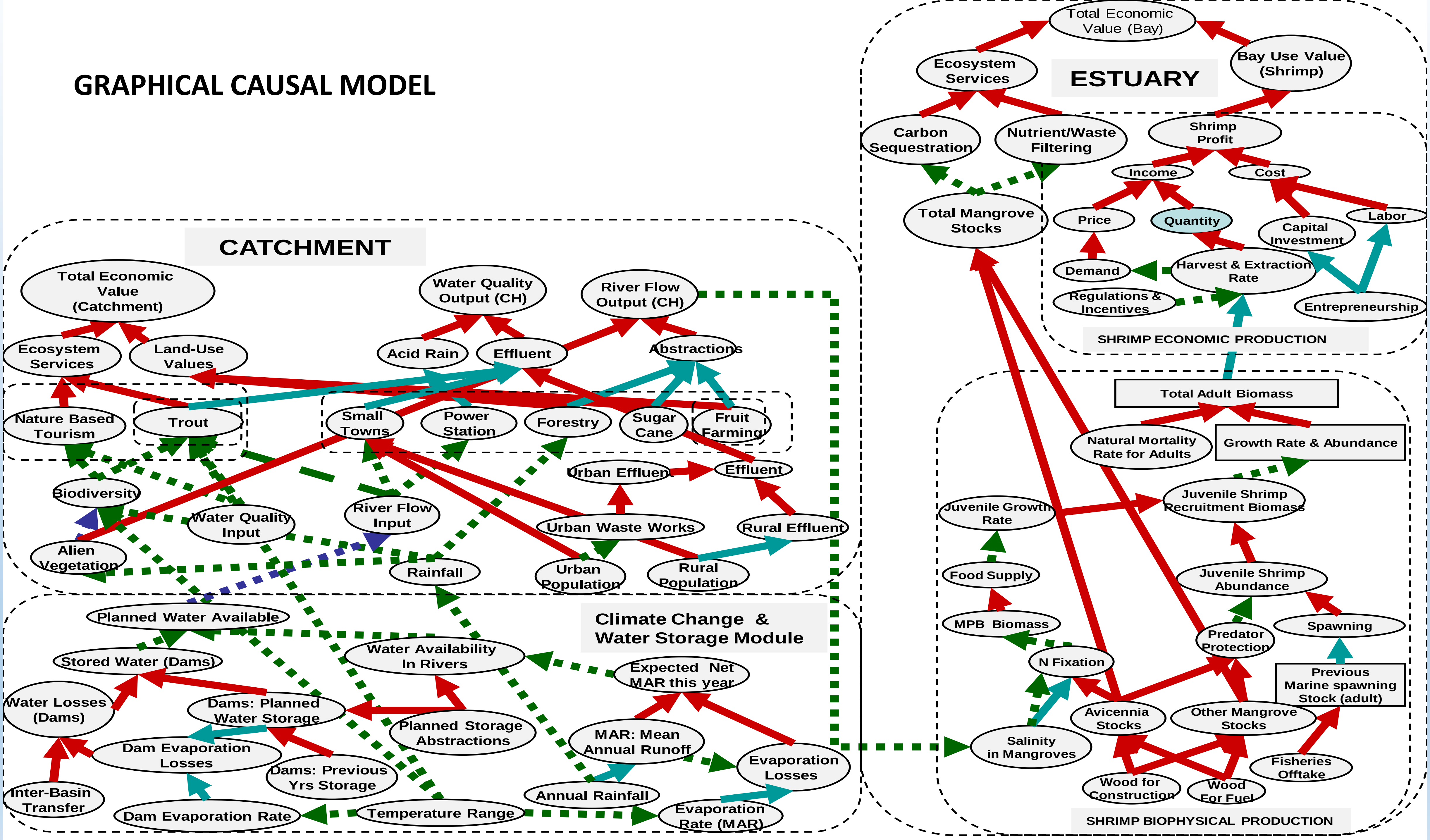
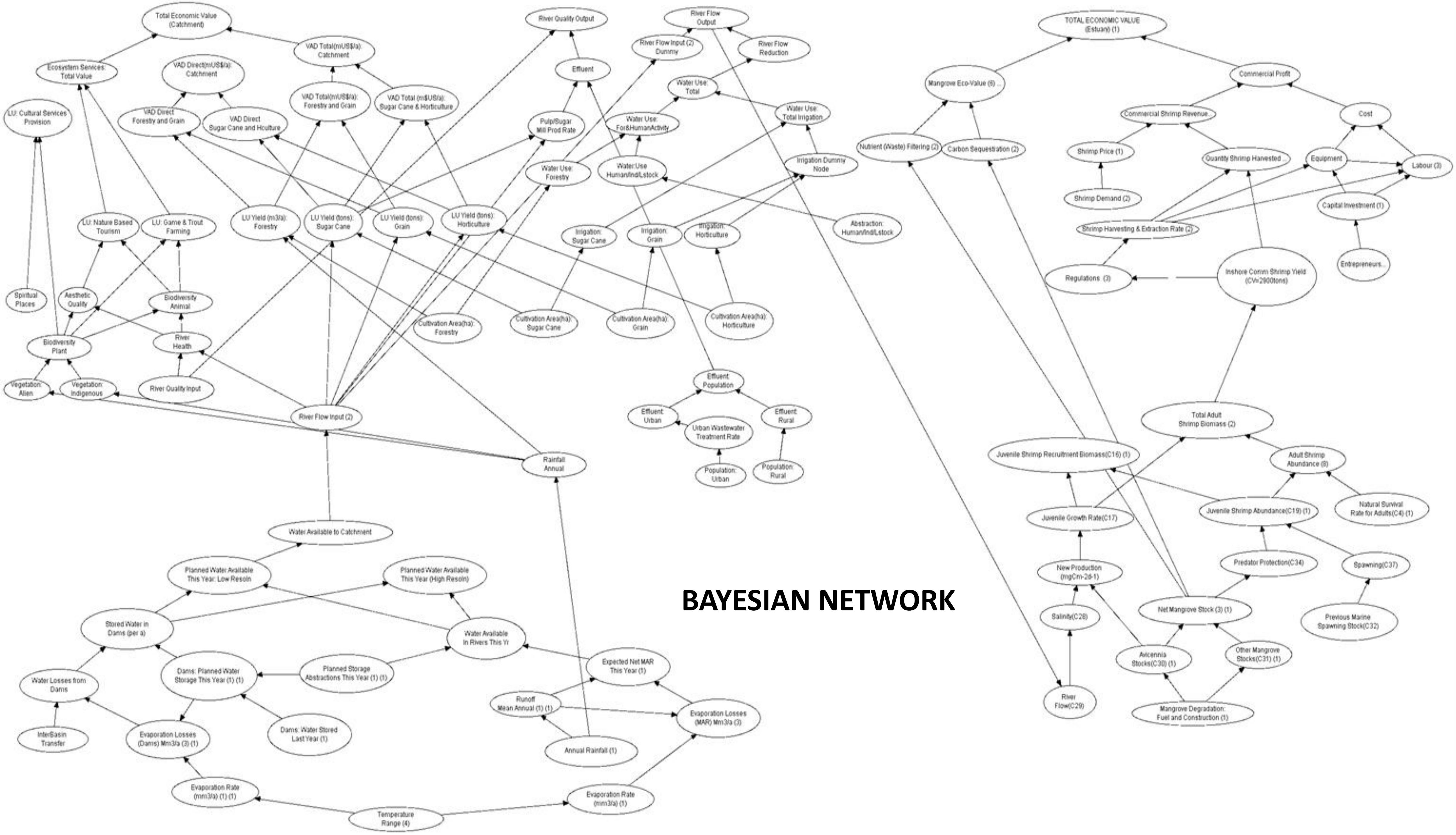


Figure 1-3 Causal-loop diagram of several important feedback loops in World3

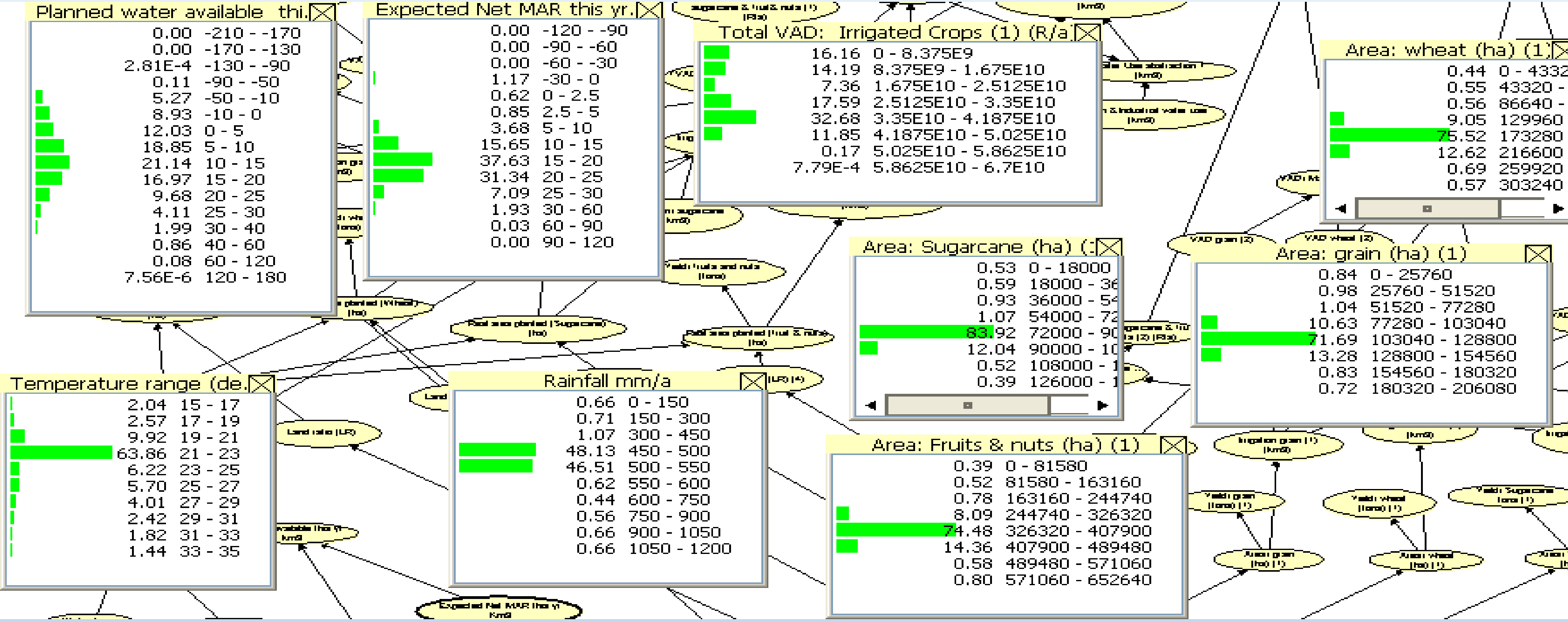
GRAPHICAL CAUSAL MODEL



BAYESIAN NETWORK



BAYESIAN NETWORK WITH PROBABILITY DISTRIBUTIONS



Converting SME opinion to probabilities

C1034: BII SCORE LIGHT USE?

* C_C904 * C_C904 / 1000000 + 0.1 * C_C904 * C_C904 / 10000 + 0.1 * Cancel OK

ssion ☐ Ignore negative states Parse Normalise

s ☐ Use bar mode Build Suggestion

C_C904?	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	
0-0.05	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.0
0.05-0.1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.0
0.1-0.15	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.0
0.15-0.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.0
0.2-0.25	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.0
0.25-0.3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.0
0.3-0.35	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.000000	0.0
0.35-0.4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.0
0.4-0.45	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.000000	0.000000	0.0
0.45-0.5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.0
0.5-0.55	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.55-0.6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.6-0.65	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.65-0.7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	1.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.7-0.75	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.75-0.8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.8-0.85	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.85-0.9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.9-0.95	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0
0.95-1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0

Examples of Systems-Modelling Projects

- Catchment2Coast (EU Fifth Framework):
  - http://www.iospress.nl/book/catchment2coast-a-systems-approach-to-coupled-river-coastal-ecosystem-science-and-management/
- SPEAR (Sustainable options for PEople, catchment and Aquatic Resources, EU 6th Framework):
  - http://www.longline.co.uk/site/spear.pdf

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