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Sediment Source Risks in Landscapes: From Field Scale Scoring to Bayesian Approaches

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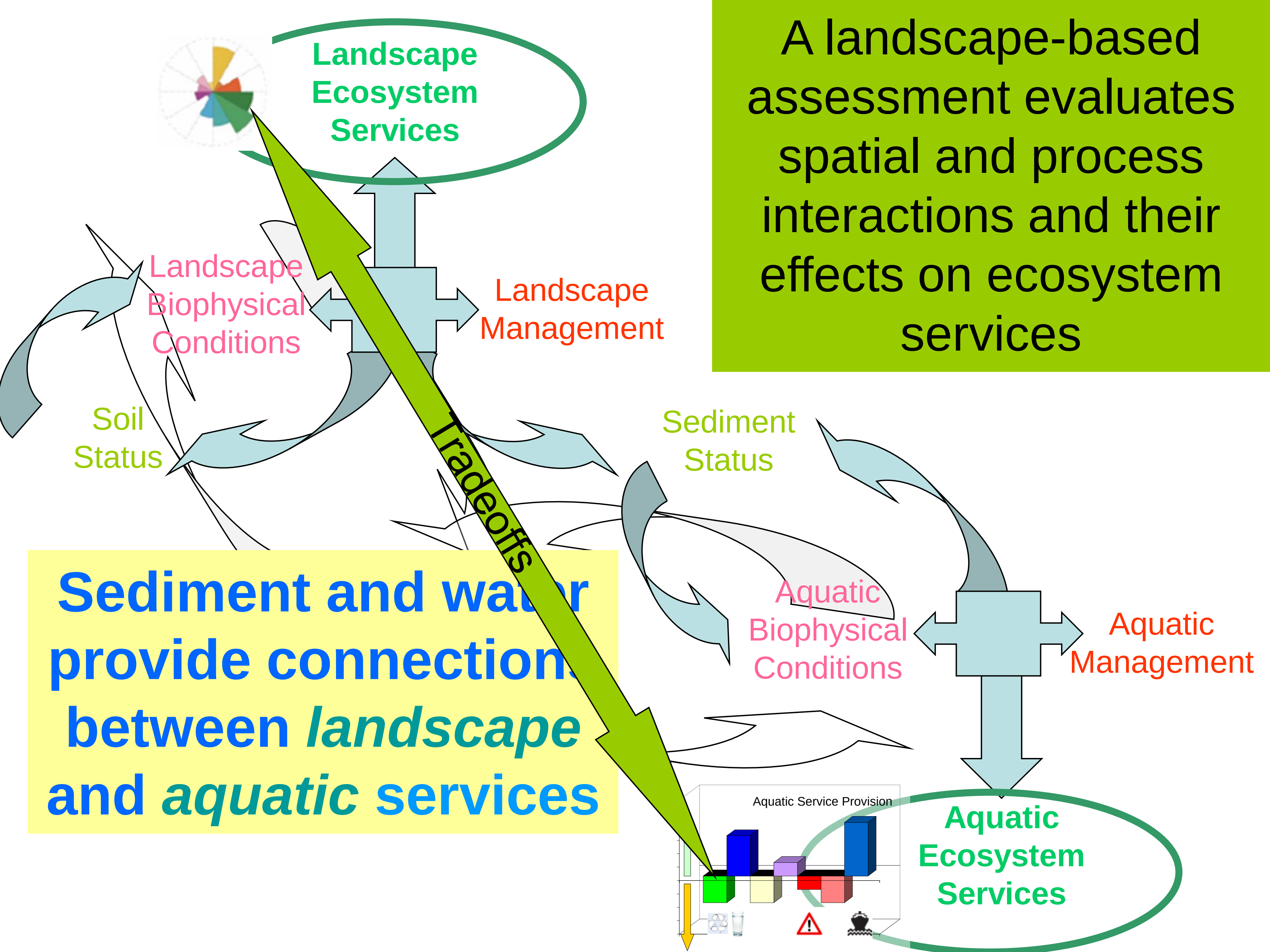
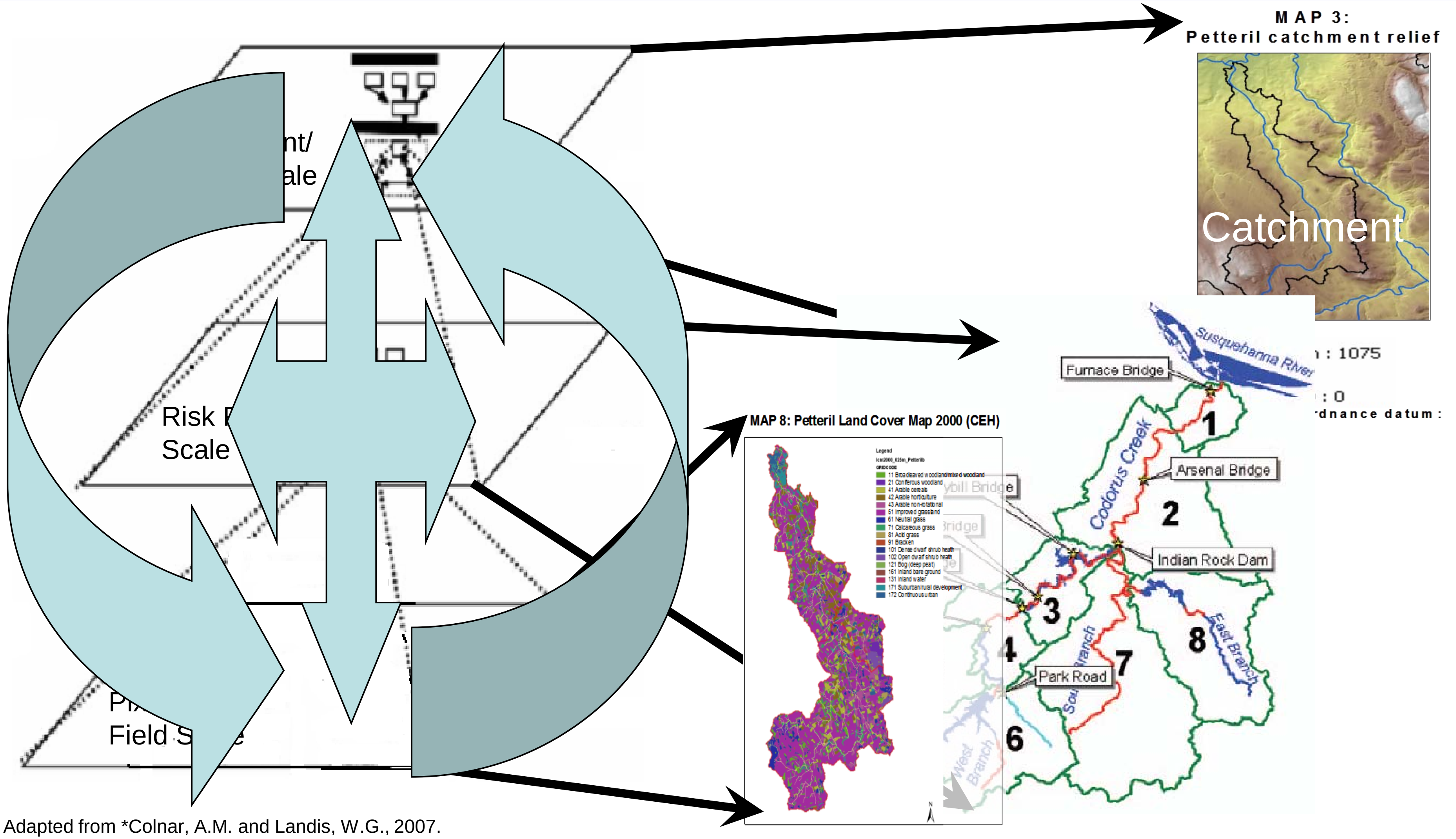

A landscape-based assessment evaluates spatial and process interactions and their effects on ecosystem services
Landscape Ecosystem Services
Landscape Biophysical Conditions
Landscape Management
Soil Status
Sediment Status
Tradeoffs
Aquatic Biophysical Conditions
Aquatic Management
Aquatic Service Provision
Aquatic Ecosystem Services
Sediment and water provide connections between *landscape* and *aquatic* services

Management of sediment impacts on aquatic systems requires evaluation of processes on land and in waterbodies at the catchment, reach and field scale



Adapted from *Colnar, A.M. and Landis, W.G., 2007.

The original Sediment Regional Risk Model (2009-2010)

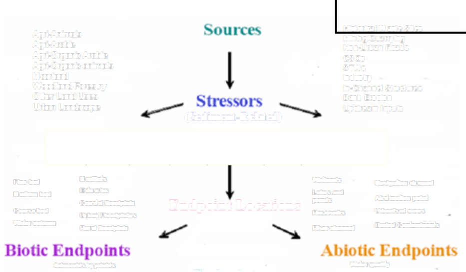
A SEA Ltd/Cranfield University effort for the Environment Agency tasked to:

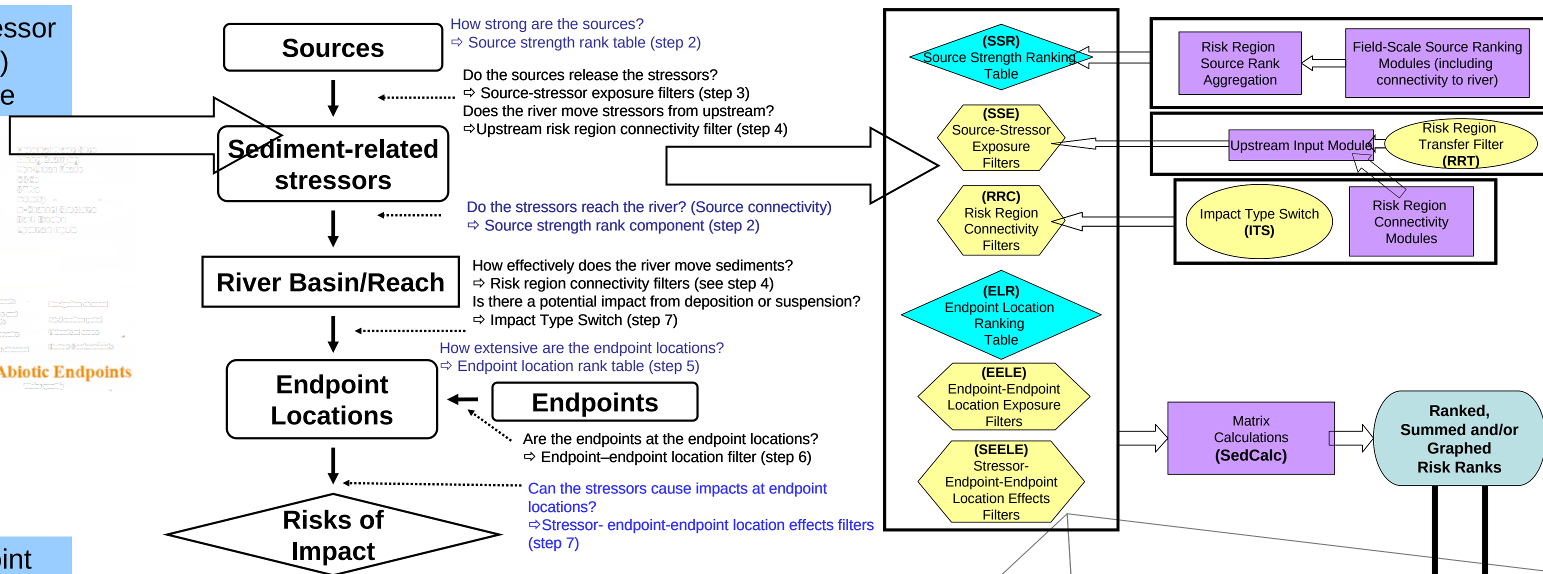
- Develop a multi-scale, spatially explicit, conceptual and numerical tool that:
  - **evaluates** the **risks** of sediment based upon land and aquatic use and characteristics
  - **ranks** pathways of **impact** between sediment sources and river basin endpoints
  - **allows** for the **prognostic analysis** of impacts of management changes
  - Using a sediment-specific adaptation of the **Regional Risk Assessment***

***Landis, W., 2005. Regional Scale Ecological Risk Assessment Using the Relative Risk Model. CRC Press, Boca Raton.**

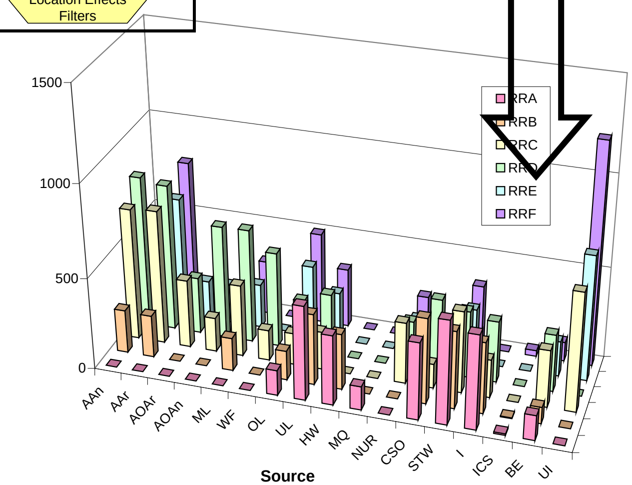
The Sediment Regional Risk Model is a systematic framework for addressing the multi-scale interactions between land and water management and their impacts on ecological and socioeconomic endpoints in watersheds

Source Class – Stressor Release (SCSR) Conceptual Table





Endpoint – Endpoint Location Impact (EELI) Conceptual Table



The model can either rank current risk pathways or predict the effects of changes in management practices

Sources

Agri-Animals
Agri-Arable
Agri-Organic Arable
Agri-Organic animals
Moorland
Woodland/Forestry
Other Land Uses
Urban Landscape

Historical Waste Sites
Mining/Quarrying
Non-Urban Roads
CSOs
STWs
Industry
In-Channel Structures
Bank Erosion
Upstream Inputs

Release...

Stressors

Generic ***Conceptual Model***. This is customised on a catchment-specific or application-specific basis

Contaminants (C) | *Nutrients (N)* | *Pathogens (P)*

Fine bed
Medium bed
Coarse bed
Water column

Mudflats
Coastal floodplain
Urban Floodplains
Rural floodplain

Endpoint Locations

Wetlands
Reservoirs
River channel

Navigation channel
Abstraction point
Urbanised areas
Buried Contaminants

Which then impact...

Endpoints

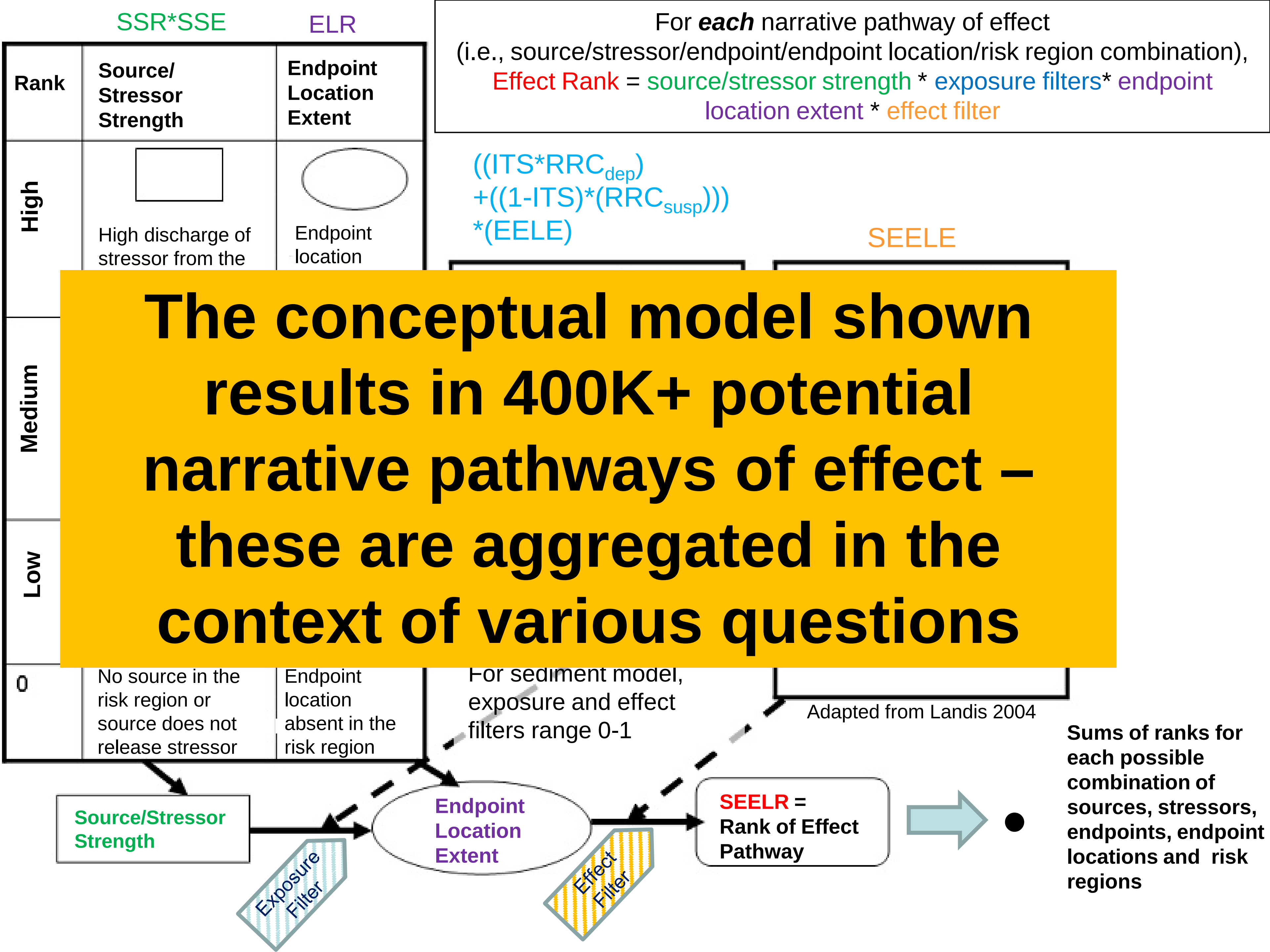
Biotic Endpoints

Salmonids/cyprinids
column feeding fish
bottom feeding fish
Invertebrates - fine
Invertebrates - coarse
Diatoms
macrophytes
Water fowl

Abiotic Endpoints

Water quality
Navigation
Coastal defence
Water storage capacity
Water conveyance capacity
MG4 grasslands
Property
Compliant sediments

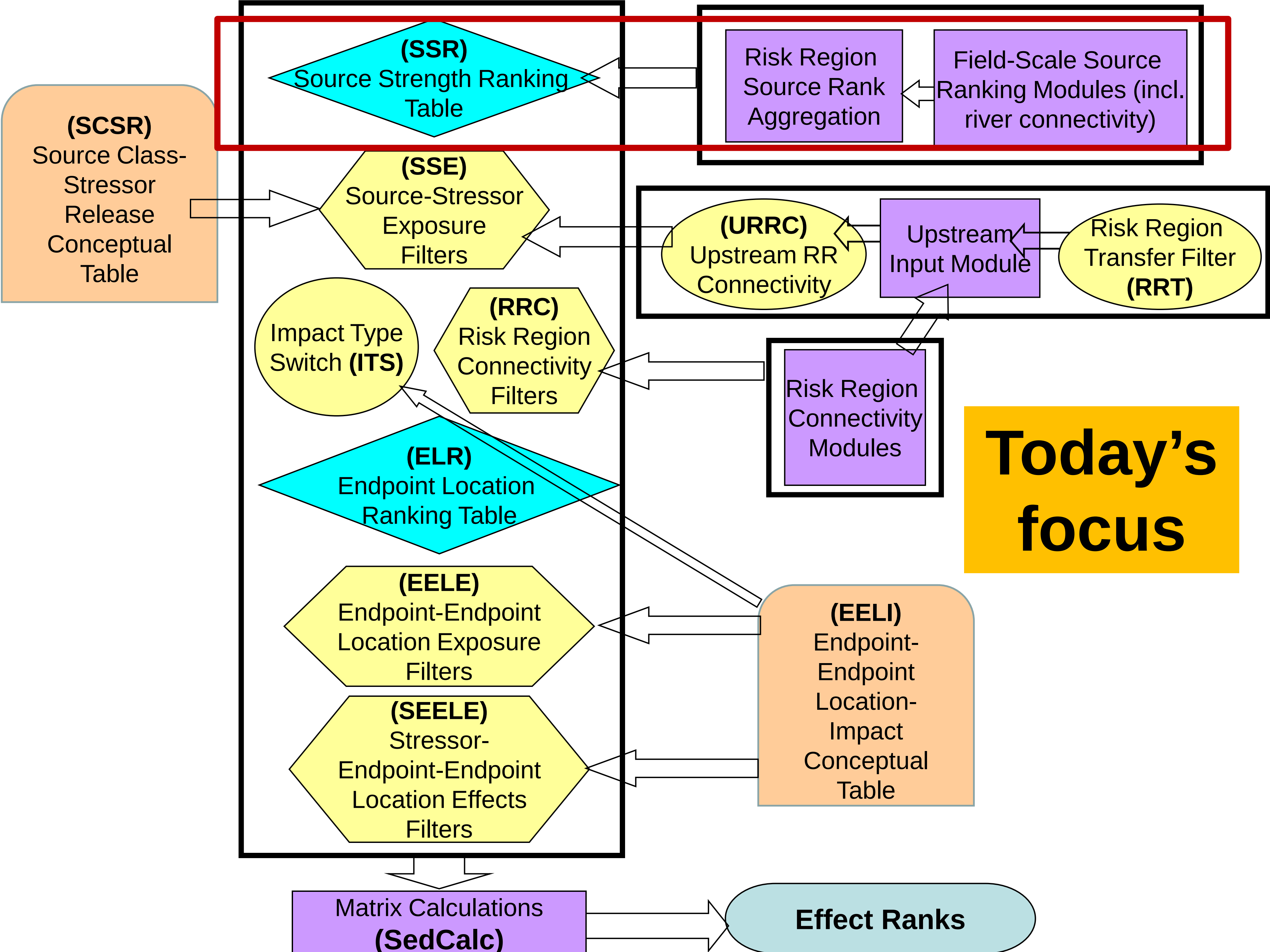
Flowchart format adapted from Maginnis, 2006

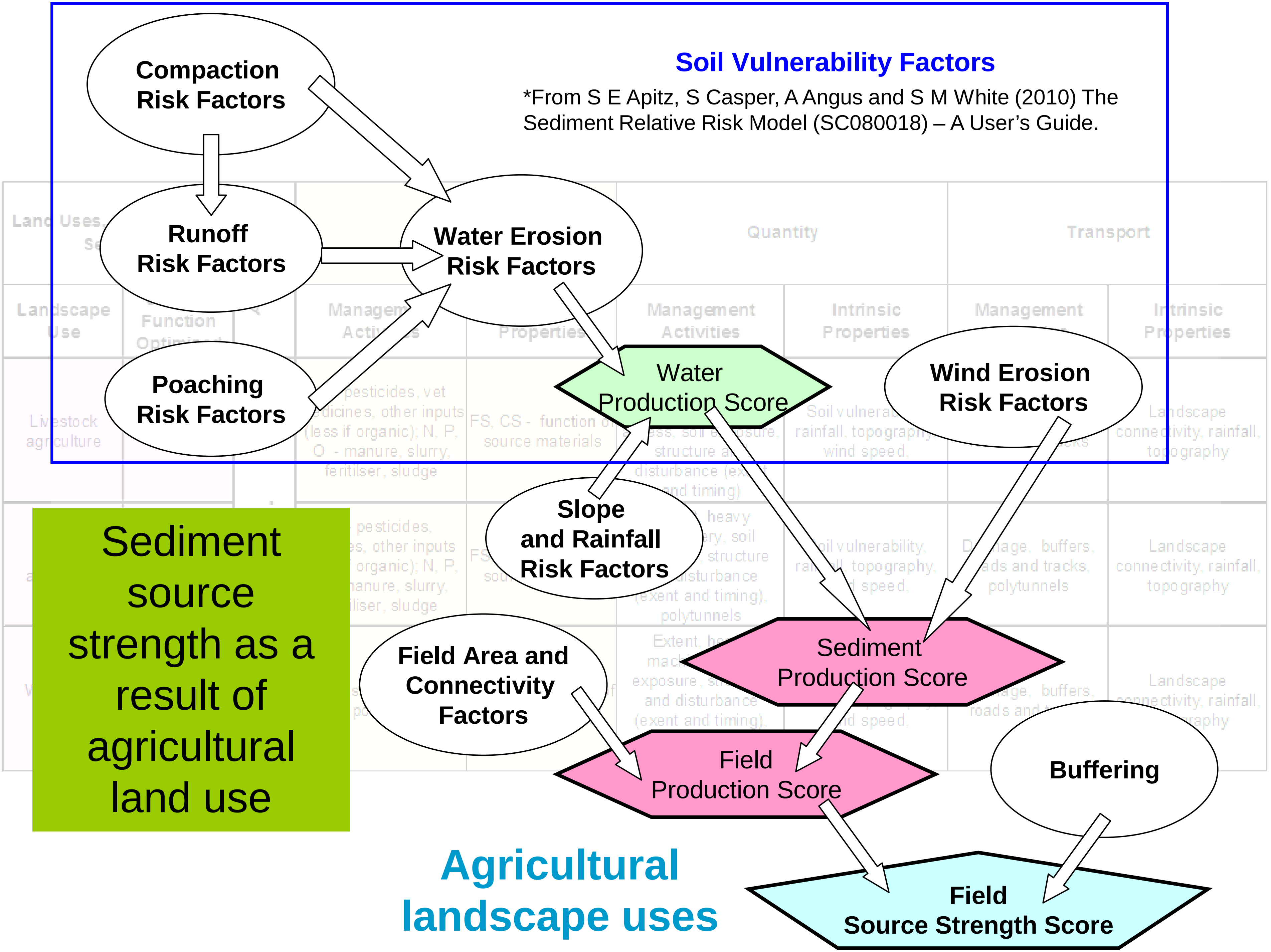


SSR*SSE
ELR
Rank
Source/ Stressor Strength
Endpoint Location Extent
High
High discharge of stressor from the
Endpoint location
Medium
Low
0
No source in the risk region or source does not release stressor
Endpoint location absent in the risk region
For each narrative pathway of effect
(i.e., source/stressor/endpoint/endpoint location/risk region combination),
Effect Rank = source/stressor strength * exposure filters* endpoint location extent * effect filter
((ITS*RRC$_{dep}$)
+((1-ITS)*(RRC$_{susp}$)))
*(EELE)
SEELE
The conceptual model shown results in 400K+ potential narrative pathways of effect – these are aggregated in the context of various questions
For sediment model, exposure and effect filters range 0-1
Adapted from Landis 2004
Source/Stressor Strength
Exposure Filter
Endpoint Location Extent
Effect Filter
SEELR = Rank of Effect Pathway
Sums of ranks for each possible combination of sources, stressors, endpoints, endpoint locations and risk regions

Sediment-specific calculation modules evaluate interacting processes at various scales:

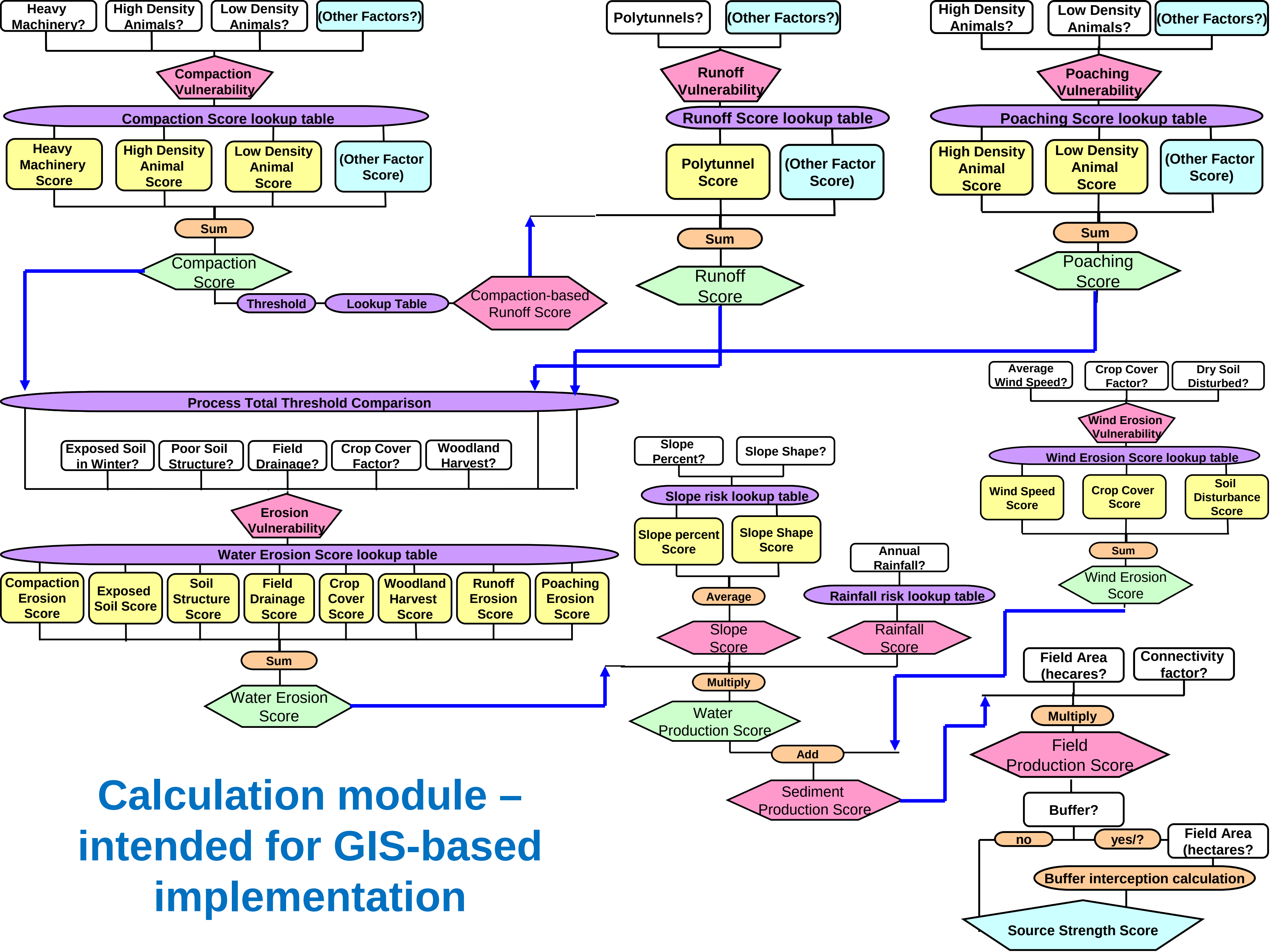
- **Sediment source strength at the field scale as a function of land use type**
  - Aggregated to the risk region scale
- The ability of river reaches to transport sediments locally and downstream at the reach scale
  - Aggregated to the risk region scale
- The likelihood of deposition
- The likelihood of resuspension
- All these modules can be run using **current data** or in **scenarios** to evaluate potential impacts of changes in management practices


(SSR) Source Strength Ranking Table
Risk Region Source Rank Aggregation
Field-Scale Source Ranking Modules (incl. river connectivity)
(SCSR) Source Class-Stressor Release Conceptual Table
(SSE) Source-Stressor Exposure Filters
(URRC) Upstream RR Connectivity
Upstream Input Module
Risk Region Transfer Filter (RRT)
Impact Type Switch (ITS)
(RRC) Risk Region Connectivity Filters
Risk Region Connectivity Modules
Today's focus
(ELR) Endpoint Location Ranking Table
(EELE) Endpoint-Endpoint Location Exposure Filters
(SEELE) Stressor-Endpoint-Endpoint Location Effects Filters
(EELI) Endpoint-Endpoint Location-Impact Conceptual Table
Matrix Calculations (SedCalc)
Effect Ranks

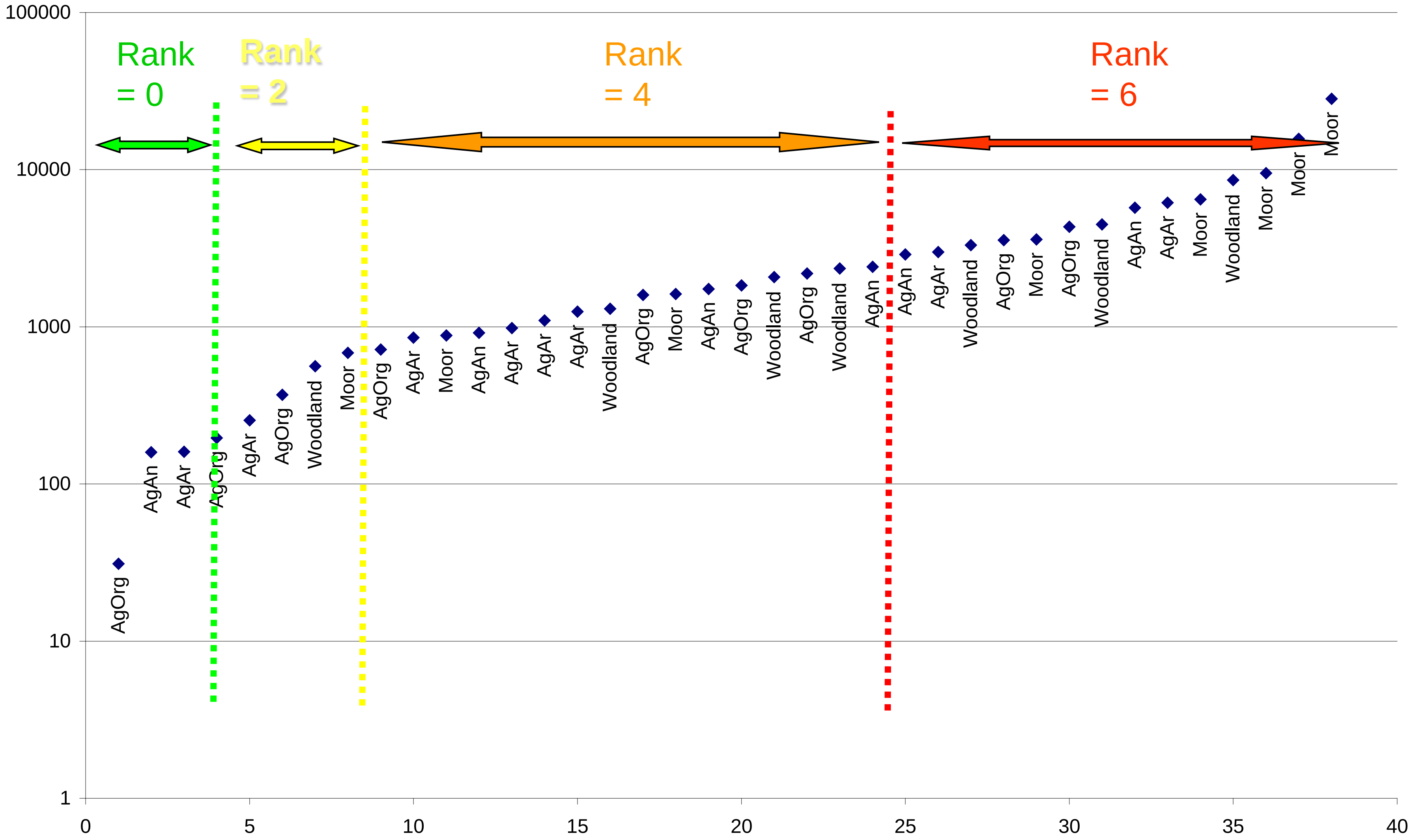


Soil Vulnerability Factors
*From S E Apitz, S Casper, A Angus and S M White (2010) The Sediment Relative Risk Model (SC080018) – A User's Guide.
Compaction Risk Factors
Runoff Risk Factors
Poaching Risk Factors
Water Erosion Risk Factors
Water Production Score
Wind Erosion Risk Factors
Slope and Rainfall Risk Factors
Sediment Production Score
Field Area and Connectivity Factors
Field Production Score
Buffering
Field Source Strength Score
Sediment source strength as a result of agricultural land use
Agricultural landscape uses

Calculation module – intended for GIS-based implementation



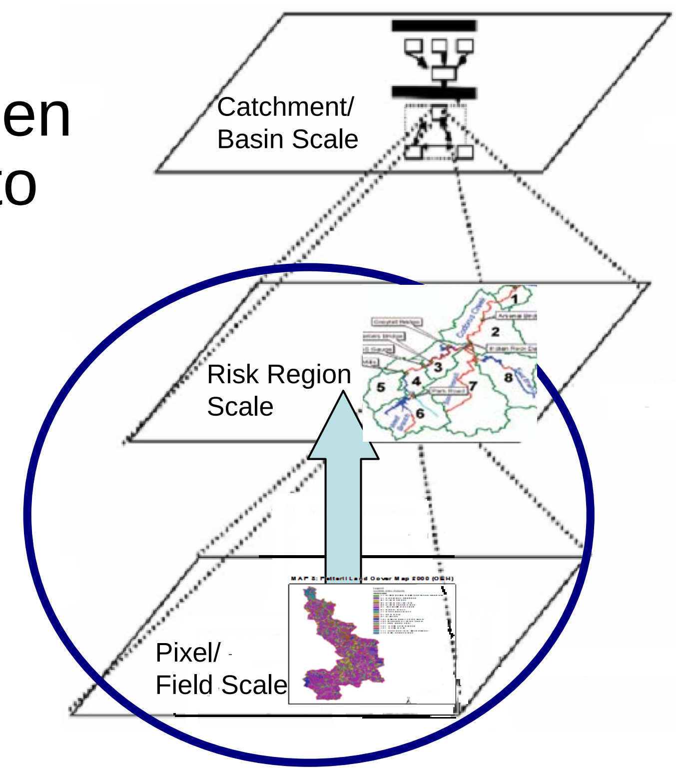
Field-scale source strengths are then ranked for SSR table based upon regional distribution of data

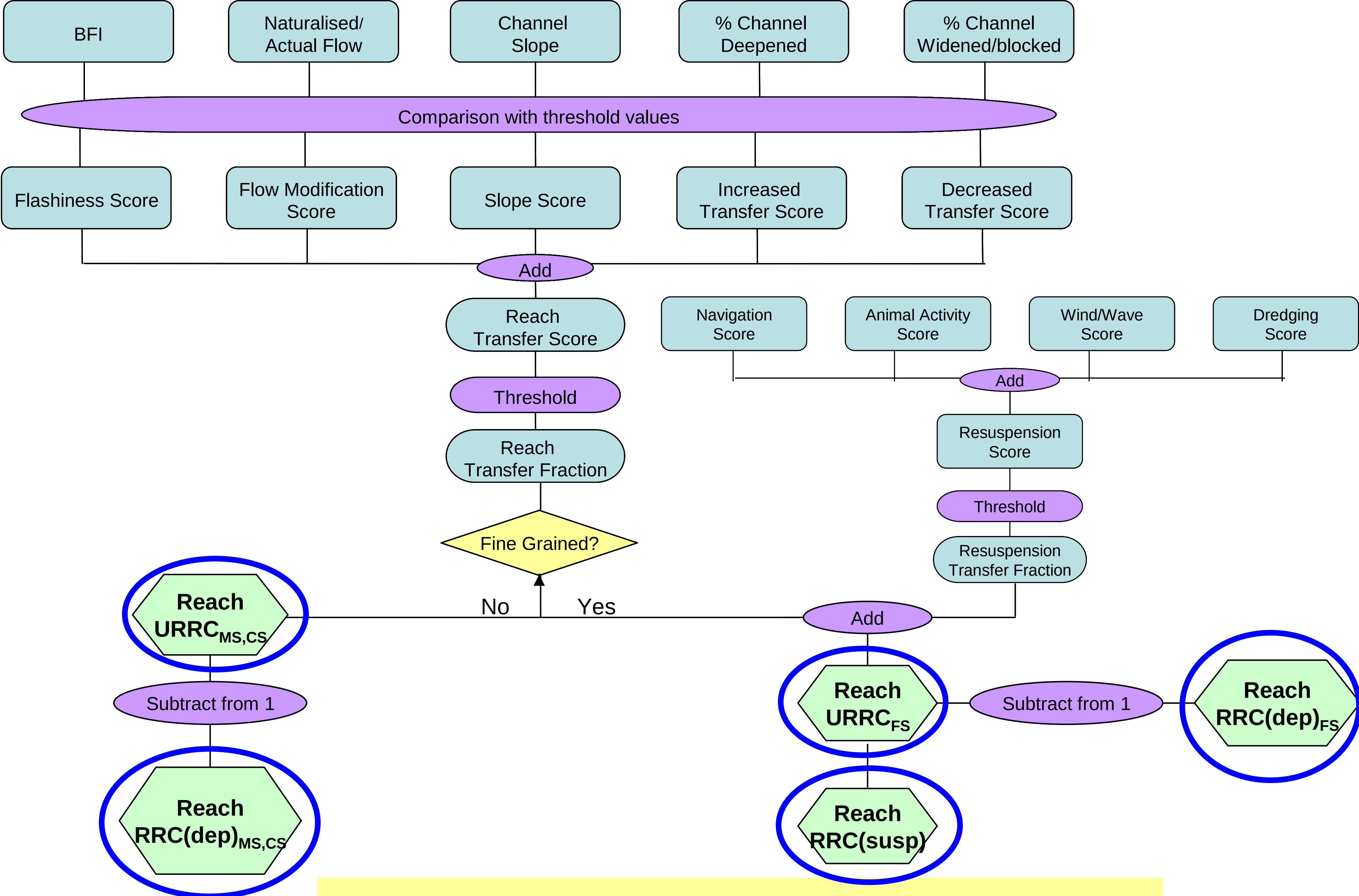


Ranks are then aggregated for Risk Regions

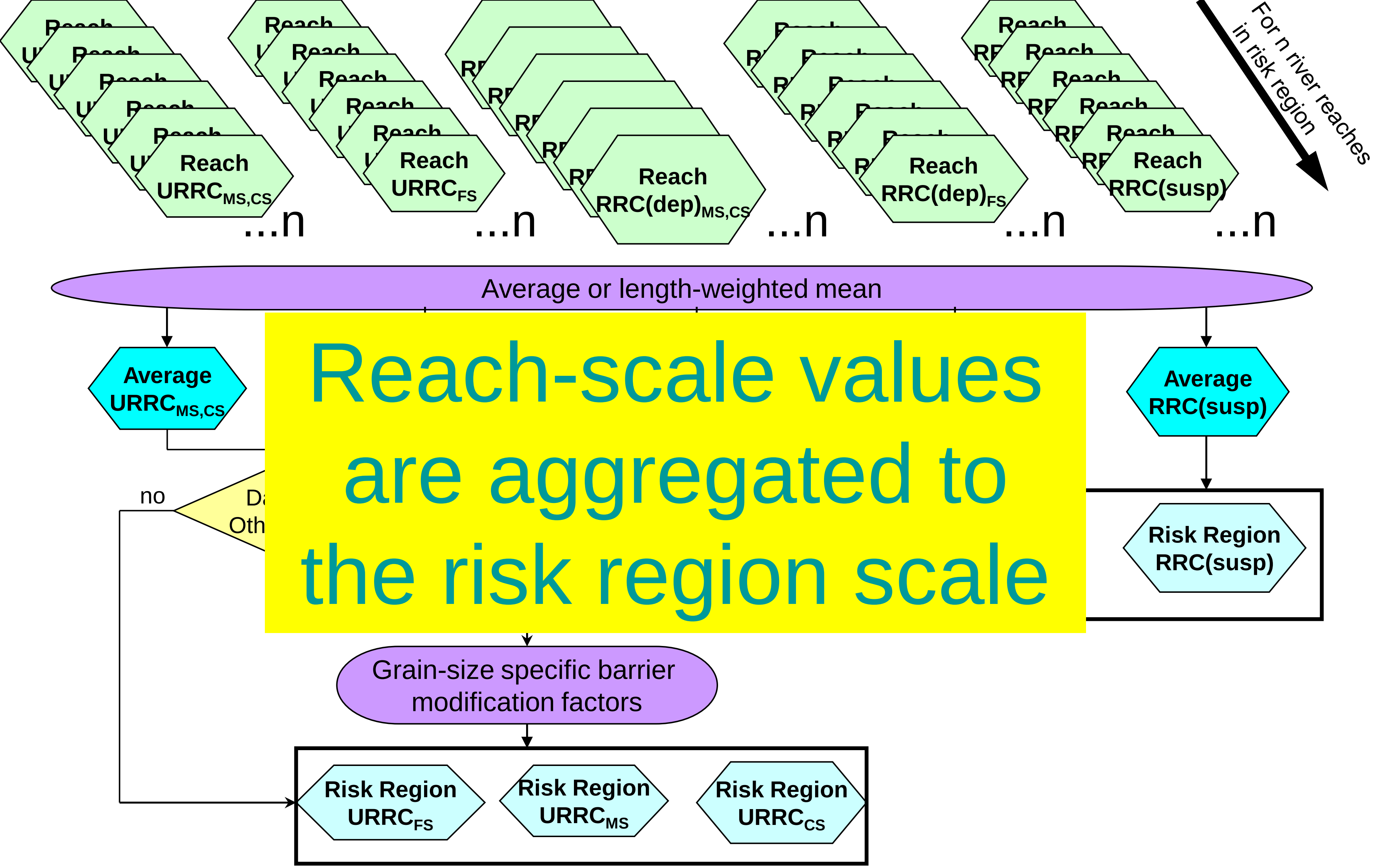
- *e.g.*, $SSR_{Ag(RRA)} = (\Sigma a_{ag} * (\Sigma((a_i)(SSR_{ag(i)}))/\Sigma(a_i))/a_T$; $i=1-n$
- This is the scale at which we address risk to endpoints and habitats

• Stressors related to source class are then "released" to risk region proportionally to risk region source strengths





River reach connectivity/exposure calculated using similar logic

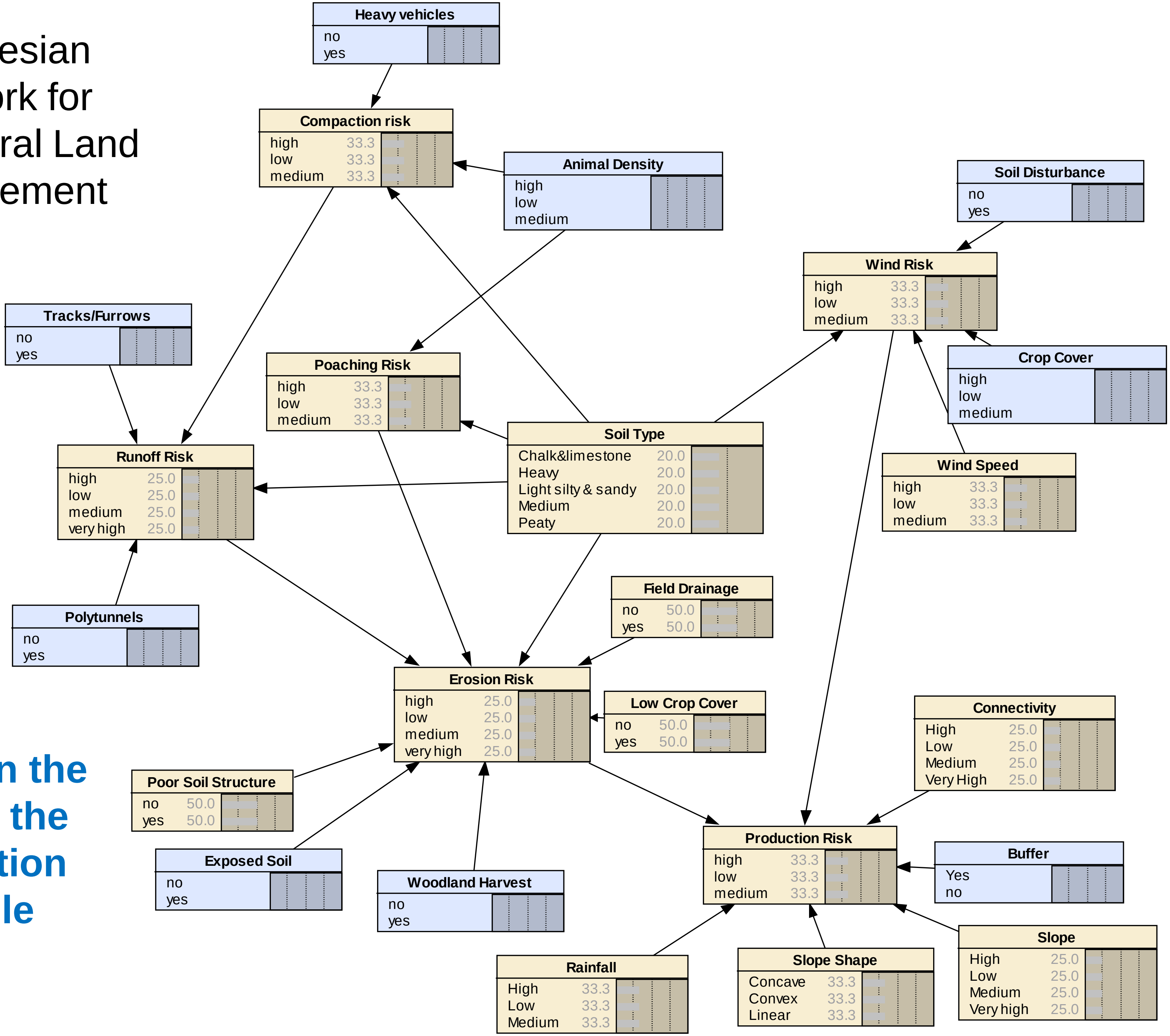


Derivation of risk region connectivity filters

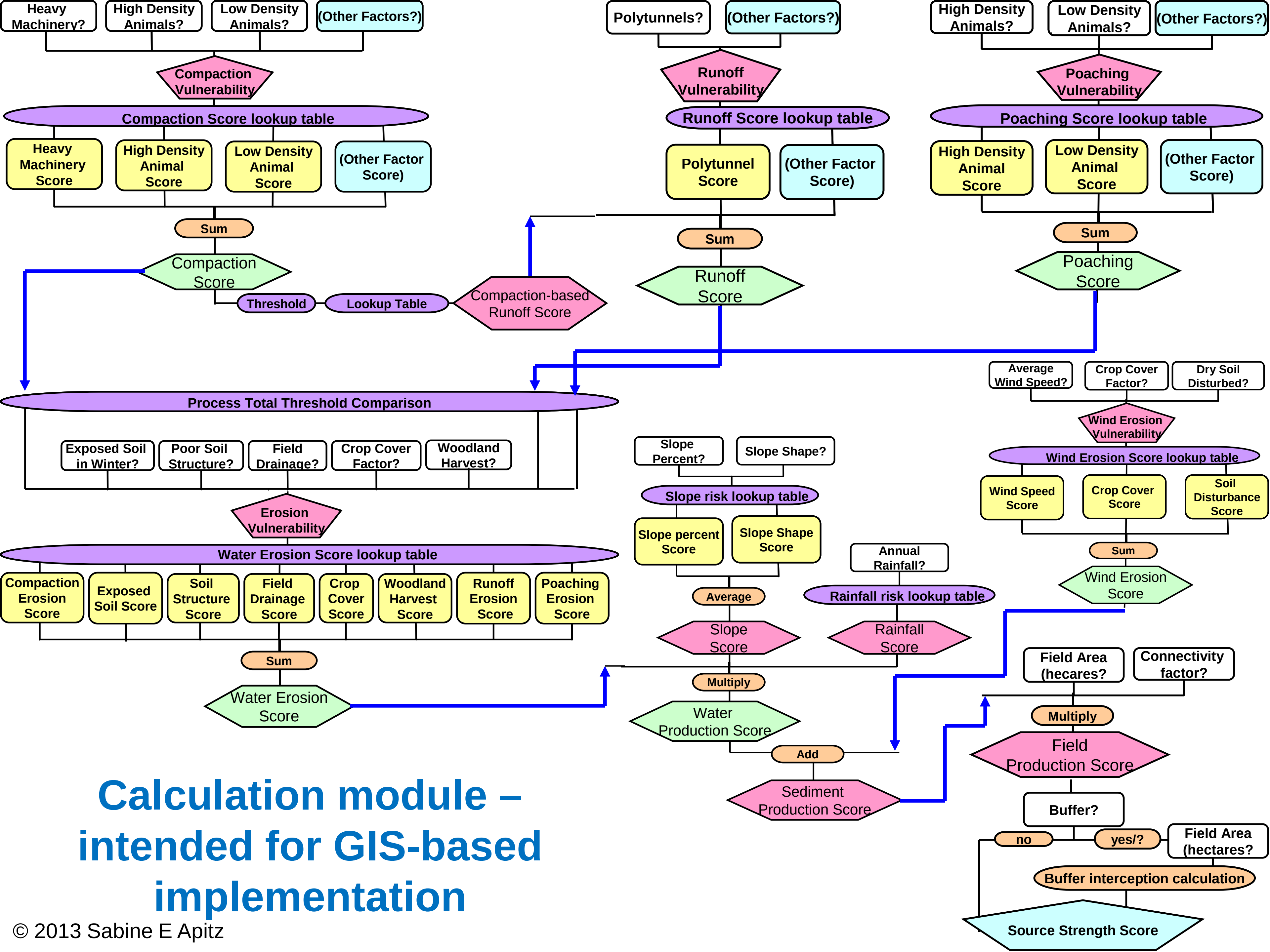
Limitations of model uptake

- Designed to accommodate site- and region-specific data and be sensitive to the management changes under EA's purview
- Source strength only requires 19 data entries (per field), easily available to EA
  - Reach connectivity also requires easily available data
  - **But both require high spatial resolution**
- The modules are data-hungry, and the EA did not have the resources to implement them
- Realistically, an expert judgement/probabilistic approach would make more sense
- Recently, the use of Bayesian networks to solve such problems has exploded
  - **I have been working to make this model more useable**

A Bayesian Network for Agricultural Land Management

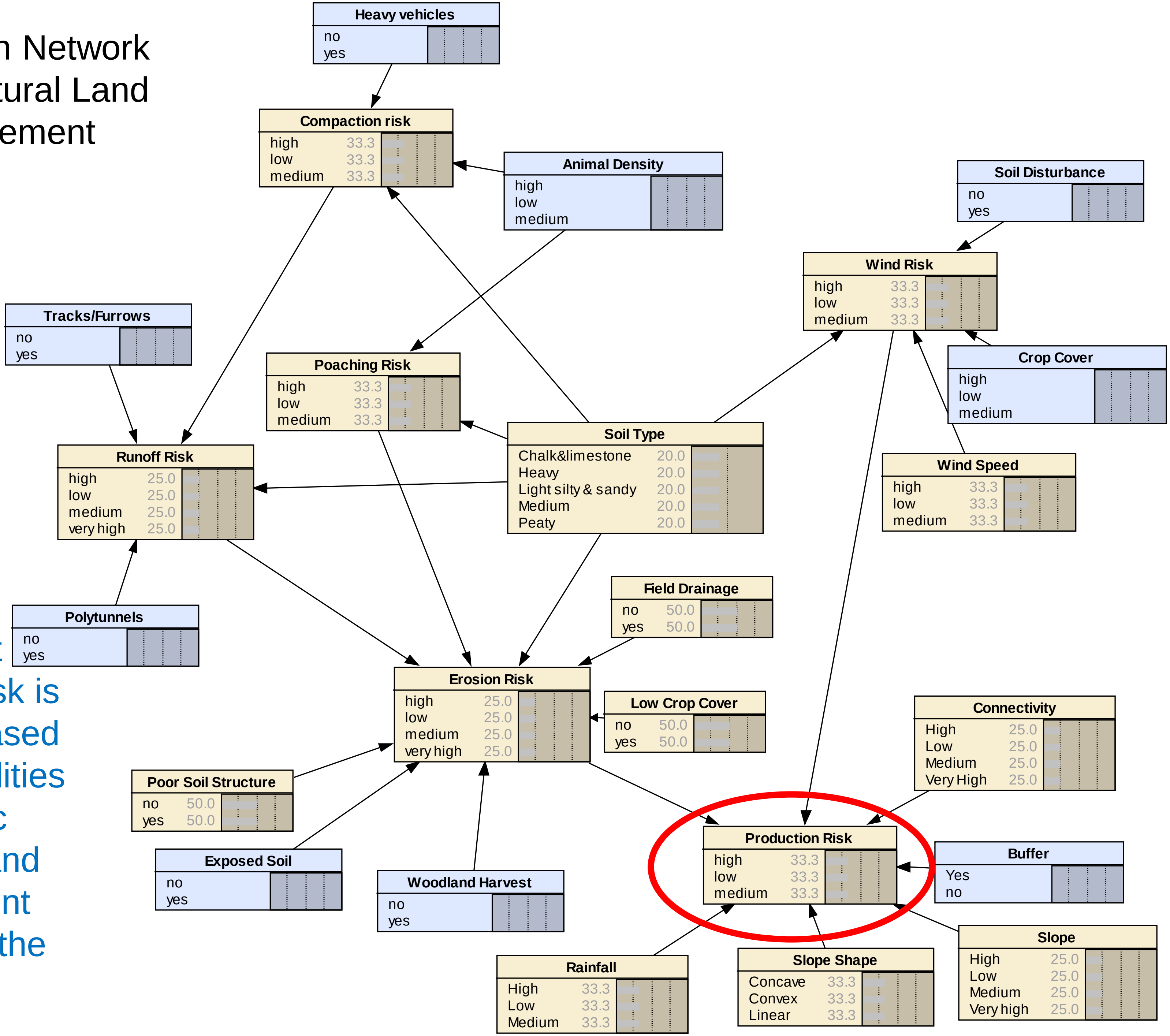


Based on the logic of the calculation module



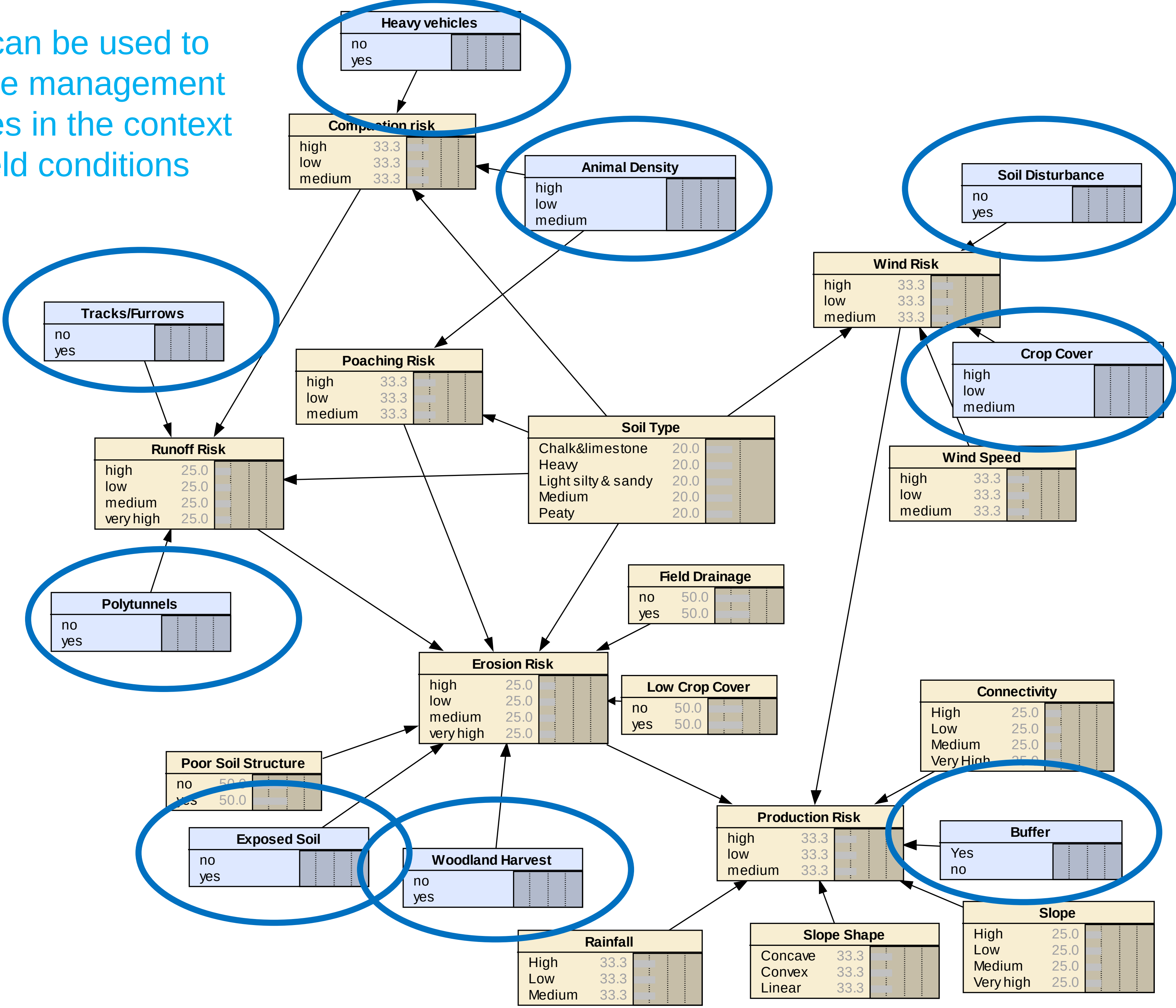
Calculation module – intended for GIS-based implementation

A Bayesian Network for Agricultural Land Management

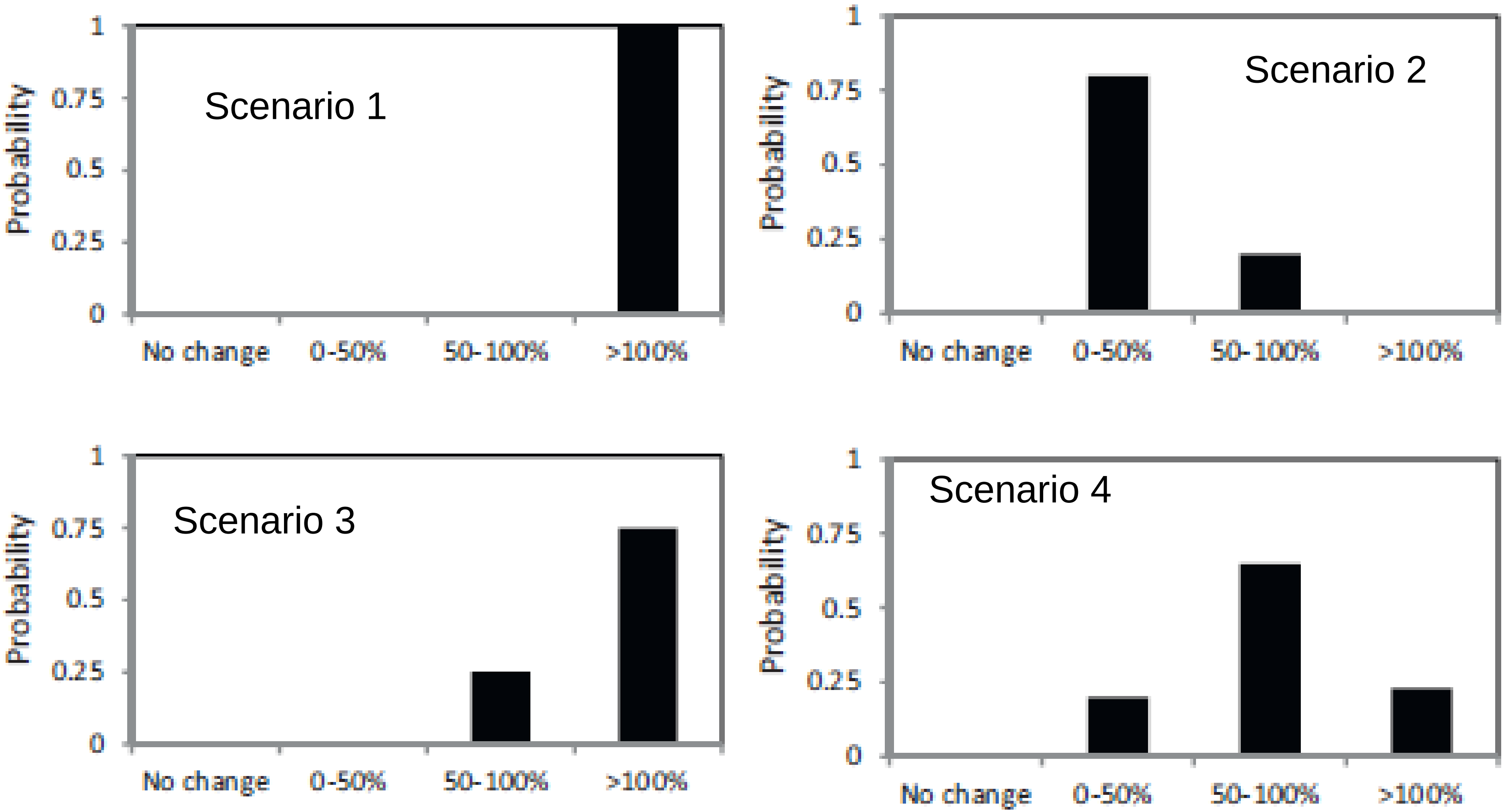


Sediment production risk is calculated based upon probabilities of intrinsic properties and management practices in the region

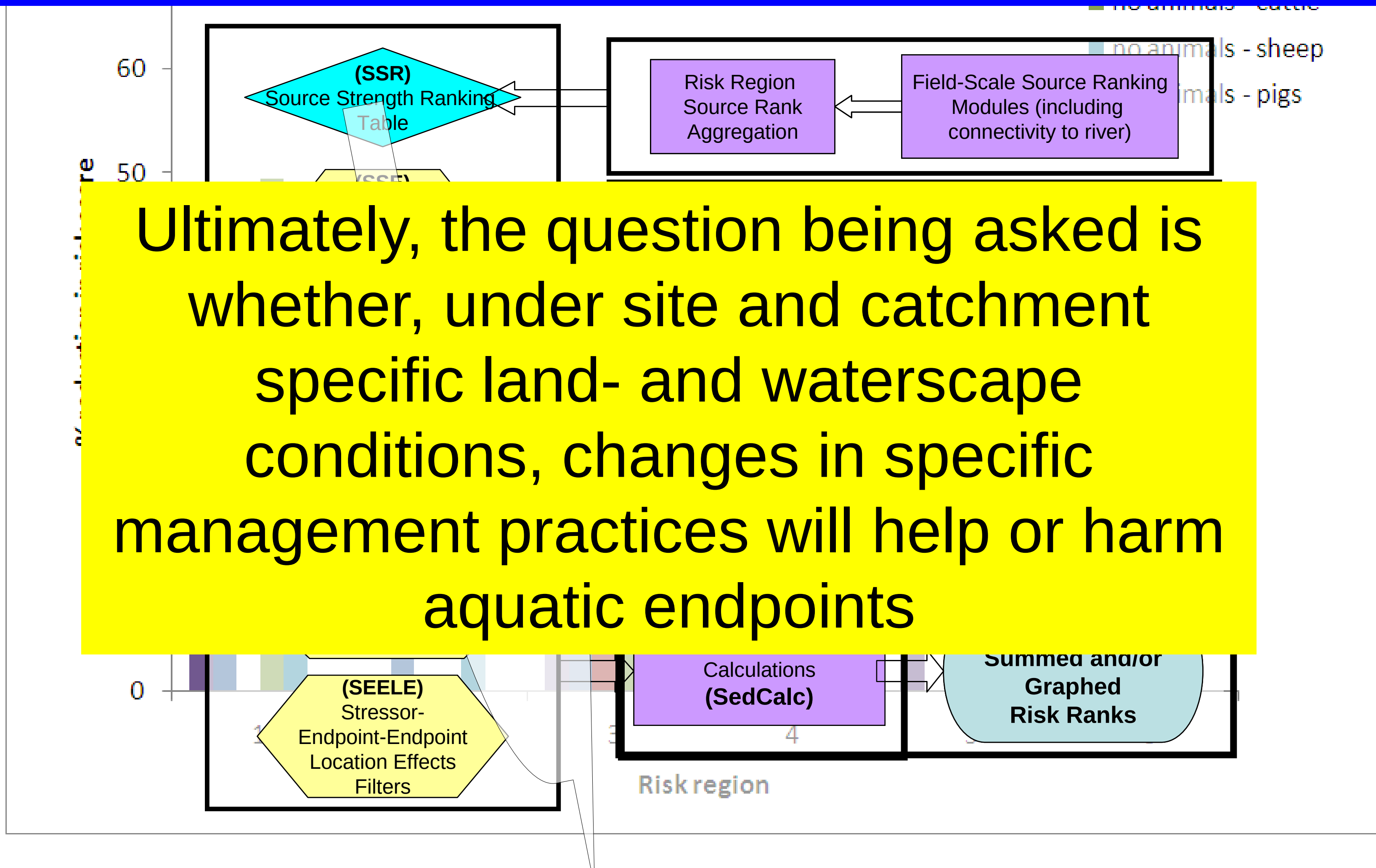
BBN can be used to optimise management practices in the context of field conditions



BBN can be used to look at probabilities of outcomes under various scenarios, allowing for more resilient, uncertainty-informed, decisions

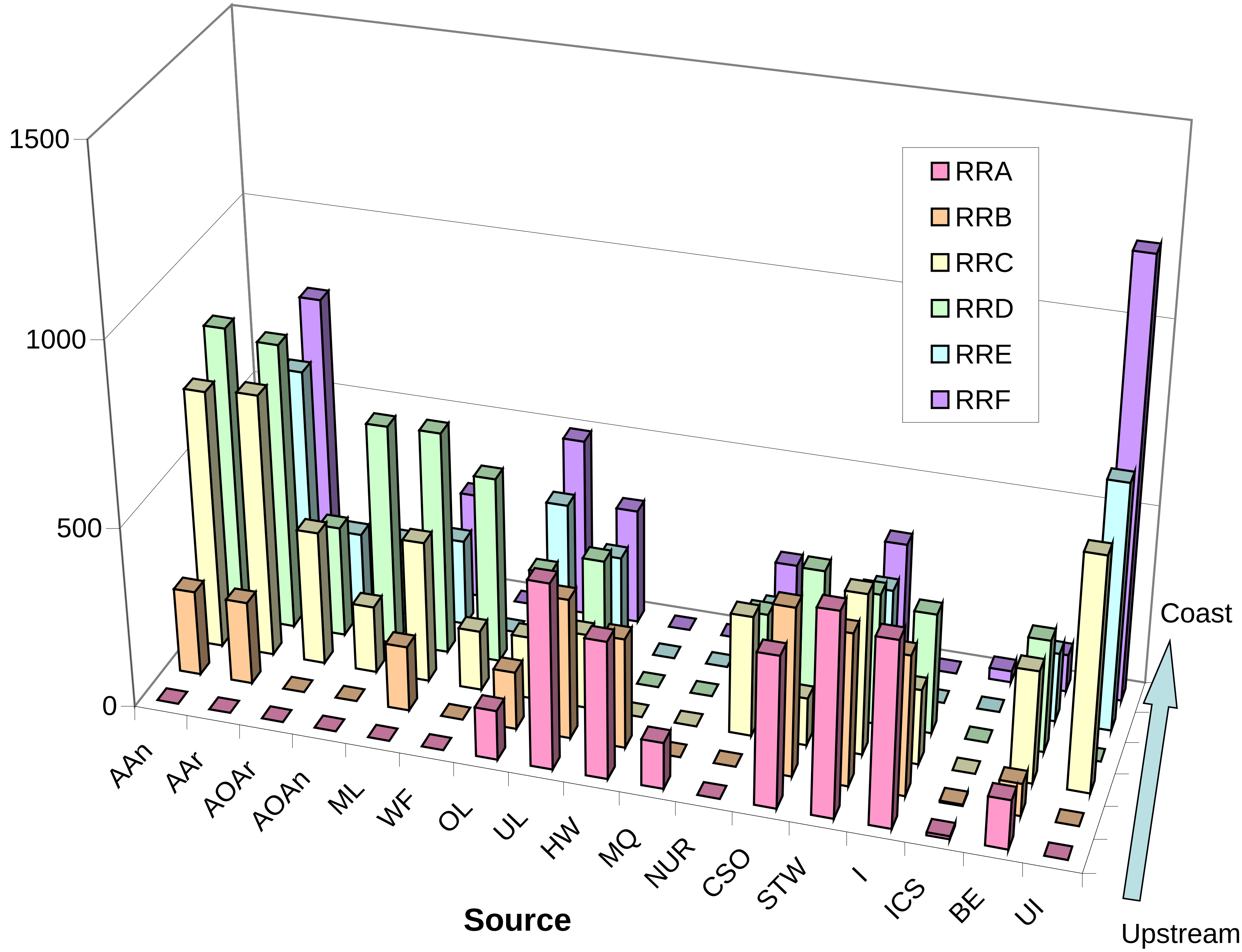


SRRM then evaluates how these changes propagate to catchment endpoints

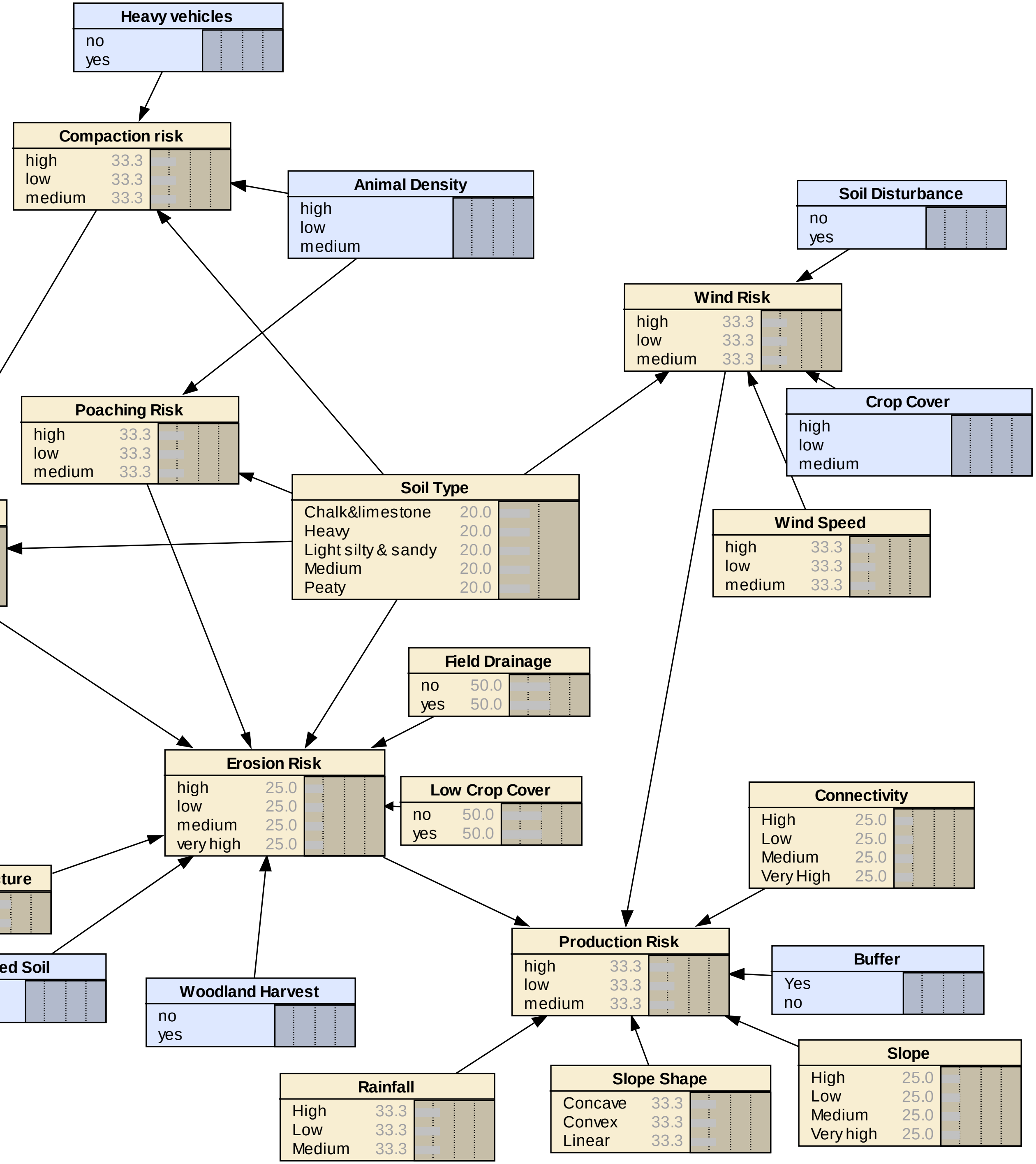


Ultimately, the question being asked is whether, under site and catchment specific land- and waterscape conditions, changes in specific management practices will help or harm aquatic endpoints

Cumulative Risks from Land Uses

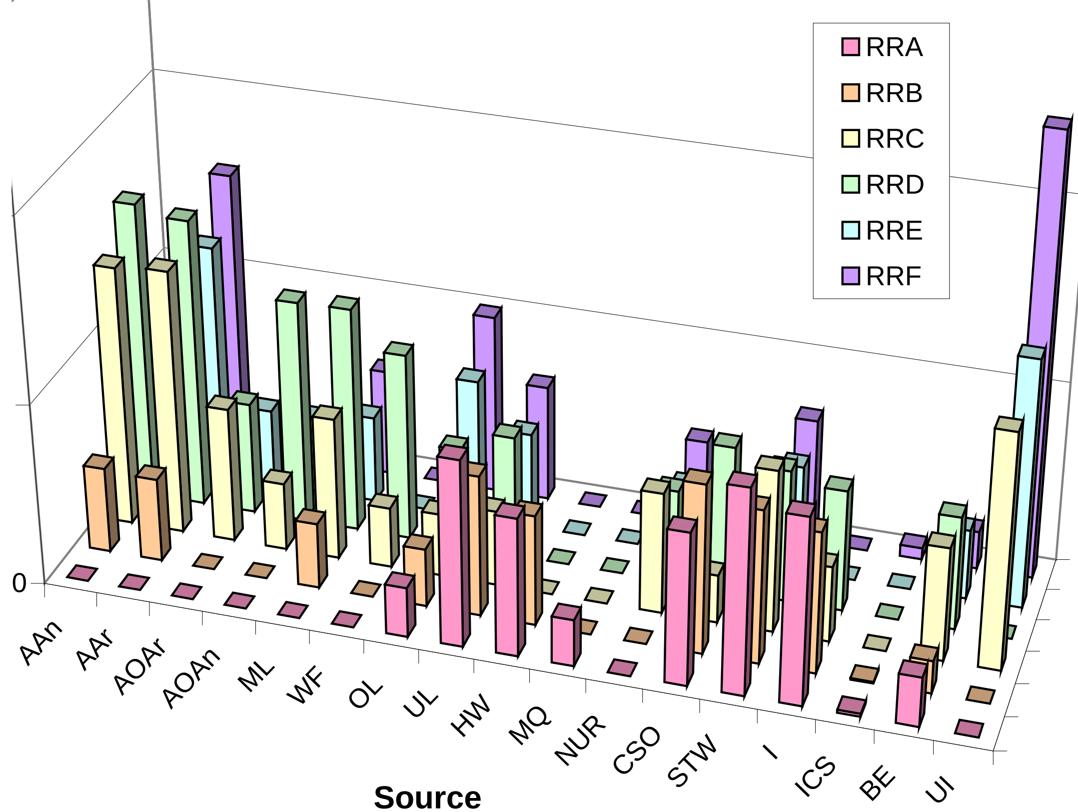


Currently working on optimising the network, an using used in the spreadsheet proof of concept to train it



Then, outputs using the two approaches will be compared

- BBN will make calculation modules more tractable and more realistic
- Probabilistic approach will inform more resilient decisions
- So far, this approach is still under development, but it should make this model more useable with limited resources



Sources: AAn-Agriculture/animals; AAr-Agriculture/Arable; AOAr-Organic Agriculture/arable; AOAn-Organic Agriculture/Animals; ML-Moorland; WF-Woodland/Forestry; OL-other land uses; UL-urban landscape; HW-Historical waste sites; MQ-mining and quarrying; NUR-Non-urban roads; CSO-combined sewage outflows; SWT-sewage treatment works; I-industry; ICS-in-channel structures; BE-Bank erosion; UI-Upstream inputs

Project Team; original project
(current work continues in my “free time”)

- **Susan Casper**, Environment Agency
  - Project sponsor
  - Model context
- **Sabine E Apitz**, SEA Environmental Decisions, Ltd.
  - Sediment-specific RRM adaptation
  - Conceptual framework development
  - Model integration and synthesis
- **Prof. Sue White**, Cranfield University
  - Land use source strength and connectivity modules, hydrology
- **Andy Angus** Cranfield University
  - Economic Analysis

For more information...

- S E Apitz (2011) Conceptualising the role of sediment in sustaining ecosystem services: Sediment-Ecosystem Regional Assessment (SEcoRA), Science of the Total Environment, 415:9-30
- P von der Ohe, S E Apitz, M Beketov, D Borchardt, D de Zwart, W Goedkoop, M Hein, S Hellsten, D Hering, B J Kefford, A Marcomini, V Panov, L Posthuma, R B Schäfer, E Semenzin and W Brack (in press). Chapter 3. Risk Assessment to Support River Basin Management in J Brils, D Barcelo, W Brack, D Mueller, P Negrel, T Track, J Vermaat (eds), *Towards Risk-Based Management of River Basins*, Handbook of Environmental Chemistry Series, Springer.
- S E Apitz, S Casper, A Angus and S M White (2010) The Sediment Relative Risk Model (SC080018) – A User's Guide. Report to the Environment Agency, SEA Environmental Decisions Ltd and Cranfield University, March 2010 (175p supplemented with a PowerPoint Guide).