NATURAL ENVIRONMENT RESEARCH COUNCIL

VALUING NATURE NETWORK
Bridging disciplines and building relevance

Please complete and send back to a.dalton@uea.ac.uk by 15th November 2012. Thank you!

Principal Investigator

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Discipline	Environmental Economics		
Role in team	Project manager and lead environmental economist		

Project team

Total number of people involved	Academics	13
	Non-academics	
Of these, how many are	Natural scientists	9
	Social scientists	
	Economists	4

Project title (<120 Characters)

Valuing the impacts of ecosystem service interactions for policy effectiveness

Project objectives

- To describe how ecosystem processes produce ecosystem services both within and across two ecosystems (Challenge 1: Incorporating complexity into valuation).
- To examine how existing valuation of ecosystem services can be ascribed to the underlying processes that are involved in socio-ecological systems (Challenge 1: Incorporating complexity into valuation).
- To identify and characterise issues of scale (spatial and temporal) that arise within and across the studied ecosystem processes, services, management and policy (Challenge 3: Incorporating issues of scale into valuations).
- To jointly assess the input processes in two ecosystems, identifying trade-offs and possibilities for joint management and policy interventions (Challenge 4: Integrating information on values into governance and decision making).
- To identify significant knowledge or data gaps and develop future research requirements.

Summary

Please provide a **one page** plain language summary of your project, aimed at a non-specialist audience. Please address the following:

- what is your project about?
- briefly state your key findings
- why are these important?
- what have you produced that other people or organisations might find useful: tools/models etc?
- who (what type of organisations) should be interested in your tools etc?

Environmental policies or management actions are often targeted at a narrow set of outcomes that do not fully consider the potential for wider outcomes. For example, management actions such as buffer strips on agricultural land may be intended to protect water quality in nearby rivers and lakes. However, such strips may also play an important role in delivering other natural benefits such as flood management, greenhouse gas mitigation, biodiversity, landscape and recreation. They may also conflict with other management aims, notably food production by taking land out of cultivation or grazing use. If these multiple outcomes, both complimentary and conflicting, are not considered then management actions may not provide an optimal. level of benefits.

Underlying the relationships between management actions and outcomes (benefits or costs to society) are complex interactions between ecosystem processes, both natural and managed; final ecosystem services and non-ecological inputs. This project aimed to explore how these interactions across terrestrial and aquatic ecosystems result in benefits that can be of value to society. The intention was then to determine how different intermediate and final ecosystem services contribute to that value in response to management action. An important aspect of this work has been bringing together an interdisciplinary team of natural scientists and economists to develop a shared understanding of how ecosystem processes and services interact to produce benefits, and to develop integrated models to capture this understanding.

An initial workshop of academics and policy stakeholders considered the interactions between ecosystem processes and final ecosystem services and how these are influenced by management and policy. The workshop highlighted how complex these interactions are (see Appendix C) and indicated that in order to make progress a narrower scope might be required for the project. This led to a focus on and an exploration of, interactions between ecosystem processes and the range of ecosystem services delivered by adopting specific management actions, namely the use of buffer strips/riparian vegetation, aimed at improving water quality.

Bayesian Belief Networks (BBNs) were identified as a suitable approach for exploring ecosystem processes and service interactions. These have the advantage of being able to utilise different types of data and knowledge; in particular expert judgement can be used to model relationships and uncertainty where data and knowledge gaps exist. We have explored the development of BBNs at two distinct scales, one a small well studied catchment (Loweswater in the Lake District) where we have detailed knowledge of biophysical processes; the other at a wider, more generic, landscape scale.as way of exploring the potential for this instrument to simplify policy-making. As these models operate at different scales they are of use to different policy audiences; although both consider similar management actions and impacts.

Although the models require further refinement (both ecological and socio-economic) to reflect the contexts in which they may be used the BBN approach is flexible and would allow users to undertake such refinement. The nature of the approach also means that the effects of changes to the system can be traced through the explicit inclusion of processes based on the interactions between ecosystems, e.g. water infiltration in buffer strips leading to reduced flooding. The modelling has also highlighted issues that need to be addressed with respect to valuation. Specifically, the lack of predictability in the ecosystem outcomes and hence their associated valuation scenarios. While these can be reflected in the probabilistic nature of the BBN, valuation then needs to account for a range of potential baseline and policy change scenarios. This is an area which requires further development and should form a key part of future work exploring how to value nature.

Your project and the Valuing Nature Network

Please provide up to **four pages** of detail regarding the following:

1. Your insights into which of the four VNN Key Challenges (Appendix A) you addressed, according to your proposal
2. How you have evolved the overall VNN conceptual framework (content of boxes and flows between) (see Appendix B)
3. Your thoughts on the future agenda for VNN research (following on from initial ideas in April's meeting)
4. Your recommendations regarding mechanisms to maintain and grow the network

1. The key challenges (2 pages)

*How can the **complexity of socio-ecological systems** be incorporated into valuations of biodiversity, ecosystem services and natural resource use?*

Our initial mapping workshop with scientific and policy stakeholders demonstrated the difficulties of such a task as even within the confines of a structured exercise; complex networks of links were identified although it was not possible to fully describe the nature of these links (see Appendix C for a summary of workshop outcomes). Our first step towards incorporating the complexity of socio-ecological systems into valuations of biodiversity was therefore to adopt a narrower focus initially concentrating on two possible management interventions, cover-cropping and buffer strips and finally concentrating on the latter alone. This was chosen as it offered the potential to explore multiple ecosystem services across our two study ecosystems (agriculture and freshwater). The network worked together to identify how the adoption of buffer strips impacts on ecosystem processes linked to the final delivery of a range of ecosystem services. Consideration was given to potential quantitative methods for enumerating the way in which adopting a buffer strip impacts on the delivery of ecosystem services. A modelling approach using Bayesian Belief Networks (BBN) was adopted as this allowed our interdiscpinary team to explore both qualitatively and quantitatively how ecosystem processes interact to produce ecosystem services and from those benefits that could then be valued. In a team workshop setting, a prototype BBN was developed by working backwards from the ecosystem service aim (in this case 'good water quality' in an ecological sense). This allowed a step-by-step construction of the relevant processes and interactions. Two parallel strands of work were then developed: 1) integrating a BBN with an existing context specific catchment scale process model; and 2) a more generic BBN at a broad regional scale. A third BBN considering green infrastructure in an urban context was also developed as part of an MSc dissertation, although this did not integrate bio-physical and socio-economic elements to the same extent.

Trade-offs between the different approaches were identified. In many respects the generic regional scale model (see Appendix D) was easier to develop as the structure and relationships were built from from the bottom up. This allowed a simplified representation of processes where the complexity of the system is implicit rather than explicit. In other words, the nodes of the BBN can be used to capture a large degree of the underlying ecosystem complexity in a very simple form. The trade-off here arises from the reduction in detail represented in the model versus its ease of use and broad applicability. To a certain extent the same need for simplification prevails even with a specific catchment scale model, but where there is greater understanding about the processes underlying some of the relationships between 'nodes' it is preferable to incorporate the process models within a BBN framework reflecting the understood complexity of the system. Our approach here was to explore how existing process models could be integrated with a BBN which includes specific policy/management measures and captures a wider range of ecosystem services and socio-economic factors (see Appendix E).

Both of our approaches were developed from a bio-physical perspective, i.e. mapping out the ecosystem process and services connections. These are then linked to a valuation element. The use of BBNs allows the specification of a 'utility' node or nodes as the network outcome; the system outputs are given utility values which in turn determine the utility associated with policy or management decisions. The generic nature of our model meant that we have not tied the utility values to actual valuation estimates although relative weightings (e.g. for water water quality) reflect typical observations based on the expert knowledge available in the project. The probabilistic nature of outcomes captured by the BBN approach highlights an important consideration for valuation, namely that the water quality and quantity outcomes of the ecosystem processes reflected in the network are not fixed but are instead probabilities for different states (e.g. water quality classifications). This has the advantage of reflecting the inherent uncertainty of such outcomes, however this is problematic from a valuation perspective in two respects: i) if using existing values (benefits transfer) these need to be apportioned across changes in probabilistic outcomes, values would need to be deconstructed across a shifting probability distribution between policy-on and policy-off scenarios; ii) the probabilistic nature of the outcomes raises questions with respect to the formation of values (where those values themselves might be subject to uncertainty) that requires specific exploration.

We have extended the generic BBN model (see Appendix F) to incorporate socio-economic factors that might influence values for both water quality (income, water use, availability of substitutes, site amenities) and flood risk (income, proximity). These extensions are not intended to be comprehensive, but do allow us to explore the sensitivity of the BBN to both bio-physical and socio-economic assumptions. A further extension would be the socio-economic aspects of land manager decision making, this would of course be important particularly if considering multiple measures or the relative value of farm incomes in policy making. Although if the BBN was to be used as a tool for stakeholder decision making some of these aspects could remain exogenous to the model.

*How can issues of **scale** be incorporated within valuations of biodiversity, ecosystem services and natural resource use?*

Our approach to issues of scale has been less well developed primarily due to the additional effort applied to considering the first key challenge. Our original motivation was that many management actions are applied at a local level but that the outcomes in terms of multiple ecosystem services arise over a range of scales. For example, wooded buffer strips may have impacts at a range of scales: local level landscape, biodiversity and water quality; catchment level flood risk; and global level climate benefits. These varying scales of outcome will also interact with varying scales of use and non-use benefit, from local to global. Similarly, the combination of ecosystem service categories, and their associated values, is scale dependent. Consequently, policy and management actions should be targeted at the appropriate scales. The timeframe over which outcomes arise due for example to lags between implementation and effect adds a further temporal scale aspect.

With respect to our generic regional level BBN we have not made the ecosystem processes and services spatially explicit, however the model can potentially be extended as with the socio-economic factors to add a spatial or temporal scale dimension, for instance by incorporating nodes that reflect level of management upake or distance decay.

Our use of both detailed catchment and generic regional models does capture the trade-off between the potentially greater accuracy of small scale (local) models versus broader scale generic models. This trade-off is relevant to decision-making and warrants further exploration in terms of the degree of uncertainty regarding outcomes that is acceptable for decision-making at different scales. The trade-off is of particular relevance to the intergration of bio-physical science and valuation, as different approaches to valuation are more or less suited to finer levels of detail. For example, stated preference methods might be insensitive to levels of bio-physical detail that result in small marginal changes.

*How do we integrate natural and social science information on values for biodiversity, ecosystem services and natural resources into governance and so improve **decision-making** and implementation?*

Our use of BBNs offers considerable potential for improved decision making as the approach lends itself to stakeholder interaction with the models. The visual nature of the BBNs mean that linkages between policy/management, ecosystem processes, ecosystem services and benefits are explicit. The data required is flexible and would allow the valuation of outcomes to be based on a range of data sources including monetary values (market or non-market), health outcomes and non-monetary assessments, these could be combined during stakeholder consultation to produce a single set of utility weights. Similarly the degree of detail represented in the BBN can be adjusted to suit different decion makers and contexts by developing or expanding particular aspects of the model or confining some details to sub-models.

2. Conceptual framework (1 page)

A limitation of the several conceptual frameworks that have been developed with respect to ecosystem services (MEA, NEA, TEEB, VNN) is their simplistic view of how ecosystems and valuation interact to produce value. Often the distinctions between management, ecosystem processes and ecosystem services are unclear and do not necessarily follow the implied linear paths.

Whilst developing our extended generic BBN to include socio-economic factors and non-ecological characteristics (e.g. substitute sites, site amenities etc.) it has become apparent that the process or context of valuation in itself will very likely influence the values people hold and express for goods and benefits. We suggest that the VNN conceptual framework can be reconceived to more closely reflect this interaction between goods and valuation context in producing values (see Appendix G).

The Natural Resources box contains a complex interaction of ecosystem process which occur both naturally and in response to external drivers to produce a range of ecosystem services. These in turn interact with other forms of capital to produce goods and services that might be valued. Our major effort has been to unpack the interactions within the Natural Resources box, although clearly the complexity uncovered does not advance the overarching concept. Instead, we suggest that before we can reach what are termed values (monetary or non-monetary) there is an interim set of interactions which we have labelled ‘Preferences’.

Within the ‘Preferences’ set there are two broad categories: ‘Goods for people’ and ‘Valuation’. The former arises from the interaction of ecosystem services and ‘other capital’. These goods are not independent of preferences as people will have a variety of preferences over the ecosystem service and capital combinations used in their production (e.g. organic versus conventional agriculture). The second category, ‘Valuation’, both reflects and shapes preferences. In the purest sense preferences are what valuation aims to measure, however the context and means by which valuation takes place will in itself affect preferences. There might be wider interactions of preferences with ‘Drivers of Change’, ‘Natural Resources’ and ‘Governance’ worthy of exploration.

It is the preferences that in turn produce ‘Values’, we argue it is these that directly relate to Governance not ‘Valuation’. It is the values, not the process by which we obtain them that feed into decisions. Of course, decision makers also have preferences with respect to how valuation is used to obtain values.

3. Future agenda (half a page)

The project brought together individuals from a key group of institutions with common interests in collecting and using data to understand land management issues at a range of scales. The opportunity to begin to explore together some of the issues surrounding valuation was excellent but very constrained by time and resource. This, together with the significant challenges being taken on by the research team, means that a future agenda will need to start where the project left off. The decision to use BBN modelling in the project resulted in many team members attempting to become familiar with the software, the underlying rationale and the approach in a relatively short space of time. It is likely that team members will continue to explore the use of BBN’s with the generic and specific examples focused on by the network, where possible, either as part of other project work or in the production of joint publications relating to the VNN work. There is considerable scope for future interdisciplinary work in this area because the tendency, at the start of the project, was to focus on getting an understanding of the linkages between different components of ecosystems and how these linked to specific management actions. This part of the work was very time-consuming and led to there being relatively little amount of time towards the end of the project to begin to work together as a group to understand how the process of valuation is linked to the production of ecosystem services and how we arrive at final values. Future work needs to continue in this area, and potentially include social scientists accustomed to measuring how humans interact with their environment to enjoy and extract ecosystem services in order to enable us to model how ecosystem components contribute to final values of ecosystem services.

There is conderable scope to progress our work with respect to several of the issues that arose from the VNN workshop in April. Particular examples include the issues of uncertainty and scale; variation in ecosystem services from different land use type or practices; uncertainty and multiple services with respect to PES; non-linearities and thresholds; and how such tools might be used for decision making where time and data are limited.

4. Maintaining and growing the network (half a page)

The network became quite a flexible entity, largely as a result of interest/availability and in one case, the loss of a staff member. The nature of the institutions involved in this Network meant that this worked well, with new staff being brought into the project for particular aspects of the work (notably the BBN modelling) whilst others lessened their commitment. What emerged was a core group of individuals who worked well together and had begun to adopt a common approach towards tackling some of the key VNN challenges. The network would like to continue to work together in this area, both to publish some of the work done during this project and to propose future work in this area. There is certainly scope for growing the network beyond the current grouping to incorporate wider expertise in the collection of social data relavant to valuation. The permenance of staff, flexibility within organisations and existing joint working offer ongoing opportunites in this respect. Within in each of our institutions and through our own wider networks we are able to draw of large pool of relevant skills and interest.

Specific project details

Please provide brief details (**100 words** for each question) to address the following:

Progress

Did the research proceed as expected and on time?
If NO give details.
Some delays were experienced largely as a result of trying to be inclusive of as many of the project team as possible, due to scheduling issues. The complexity of the ecosystems being considered also meant that the development of our socio-ecological models took longer than anticipated. We incorporated approaches and team members not included in the original proposal, specifically expertise in and use of Bayesian Belief Networks. Given the interdisciplinary make up of the team our exploratory process of working together was as important as the scientific outcomes.

Was there any significant change in the research compared with the original proposal?
If YES give reasons for changes.
We originally intended to hold a second more policy focused workshop roughly mid-way through the project. However the mapping exercises we undertook in our first workshop indicated that we should focus on a formal method of modelling the complex interactions. Therefore we used those resources to help develop our BBN approach. We intend to continue with the development of this approach in our ongoing research which will offer opportunities for future policy engagement.

Were there any circumstances that aided or impeded research progress?
If YES explain how the work was affected and how any problems were overcome or opportunities exploited.
Our work was aided by the open-mindedness of team members. This was possibly due to the applied nature of much our previous research which has involved similar policy contexts and existing explosure to interdisciplinary working albeit in different teams. The work was impeded to some extent by different use of terminology highlighting the need for initiatives such as the VNN to develop a common language for ecosystem services. Our different understanding of the systems being studied also slowed progress but reaching sufficient common understanding was key to successful interdisciplinary work.

Publications

Dissemination of results.
List the following types of output: papers (both published and in press) and reports directly arising from the research; conference proceedings; book chapters; etc.
We propose to continue the development of our models with the aim of preparing journal papers covering the Loweswater and generic BBNs, these would also be submitted to relevant conferences. The policy engagement aspect of the project was not developed within its lifespan, but we intend to use our existing policy and stakeholder engagement networks (EKN, NERC Water Security Knowledge Exchange Programme, Ecosystem Approach Working Group, SRUC's Rural Policy Cente) as well as informal engagement with stakeholders through other project work as dissemination routes.

Results and outputs

Have any significant datasets been generated from this research?
If YES give details.
The tangible outputs from the research have been the BBN models rather than data (although data and knowledge are inherent in these models).

Were there any circumstances that aided or impeded research progress?
If YES explain how the work was affected and how any problems were overcome or opportunities exploited.
The emerging complexity of the systems we were studying meant that we had to adapt our approach and concentrate the work within the project team rather than involve a wider stakeholder group. Although this impeded the research with respect to the original proposal it did aid the interdisciplinary work within the team. Ideally we would have had an opportunity to feedback on the construction of the BBN's to some of the original participants in our stakeholder workshop, but time and resources did not allow for this.

Results exploitation and knowledge transfer

Who do you think are the main users of this research?
Include any that apply: industry (please specify which sector); policymakers and regulators (e.g. Defra, Environment Agency), NGOs (e.g. RSPB, conservation bodies; other academics).
The outcomes of this research require further refinement to create fully operational models that would be of use to policymakers and potentially land managers. However, the nature of this modelling process is iterative towards a more (rather than fully) requisite model that could involve stakeholders applying it to particular contexts. The current model would be of use for policymakers, regulators and NGOs (such as the Environment Agency, Scottish Environment Protection Agency, Natural England etc), although the broader approach could be used as a decision support tool for business.

Have any potential beneficiaries and/or users of the research outputs (in particular non-academic research users, such as private or public sector organisations) been involved at any stage in the research activity and/or been informed of the research outputs and achievements?
If YES give details.
Potential users were involved in an initial workshop that mapped out linkages across ecosystem processes, services and policy aims. These incluced policymakers and academics. Our future knowledge exchange and dissemination activites will be aimed at these groups.

Has the research led to any further collaborations with potential users or other academics?
If YES give details.
Through our initial stakeholder workshop and other indirect activities (workshops, meetings etc) the research has opened up the potential for future academic collaboration and links to the wider stakeholder community. Links between this and another VNN network may allow for wider collaboration on this approach (in terms of users and academics) in combination with the conceptual framing of ES provision reached within the other network. Though this is likely to be a process which requires time and resource.

Science in society

Has an opportunity arisen to promote the public understanding of the scientific results from this research?
Give details of work/activity undertaken
The work has not directly involved interaction with the public. Simple BBN type models could be useful in developing public engagement and understanding. The approach could be used to inform future valuation studies which would public understanding in a more limited sense, for example as a tool in participatory valuation.

Interdisciplinary working

To what extent did the project enable new working relationships a) between different academic disciplines and b) with non-academics?
Please give details
The project team comprises soil scientists, ecologists (terrestrial and freshwater), modellers and environmental economists. It has expanded on existing relationships and allowed new relationships to develop both within and aross these disciplines. These disciplinary areas were also reflected in the variety of stakeholders who have also expressed an interest in the project and were involved in our workshop. The project was also linked to two interdisciplinary dissertations by MSc students studying Ecological Economics.

What were the main challenges of working as a team consisting of people from different disciplines/sectors?
Please give details
The key to working across disciplines has been open-mindedness and a willingness to follow the processes of each other's spproaches. In some respects this has been easier than within discipline working as we do not have competing paradigms or agendas. We have also been working towards understanding a common issue. Instead the challenges have arisen with respect to terminology and conceptual frameworks which, although not conflicting, may not completely align. This is one of the ongoing challenges of working in the area of ecosystem services, but the resolution of these differences is a useful part of the research process.

What methods did you use to successfully address these challenges?
Please give details and also include any recommendations for future VNN research.
The use of BBNs as a modelling approach has directly allowed interdisciplinary working. The approach is not rooted in any one disciplinary field and can incorporate the variety of data and knowledge held by multiple disciplines. The graphical nature of the models produced also makes interactions and outcomes explicit.

Anything else?

If there are any other outcomes from your project that have not been captured above, or if you have any further comments, please add them here

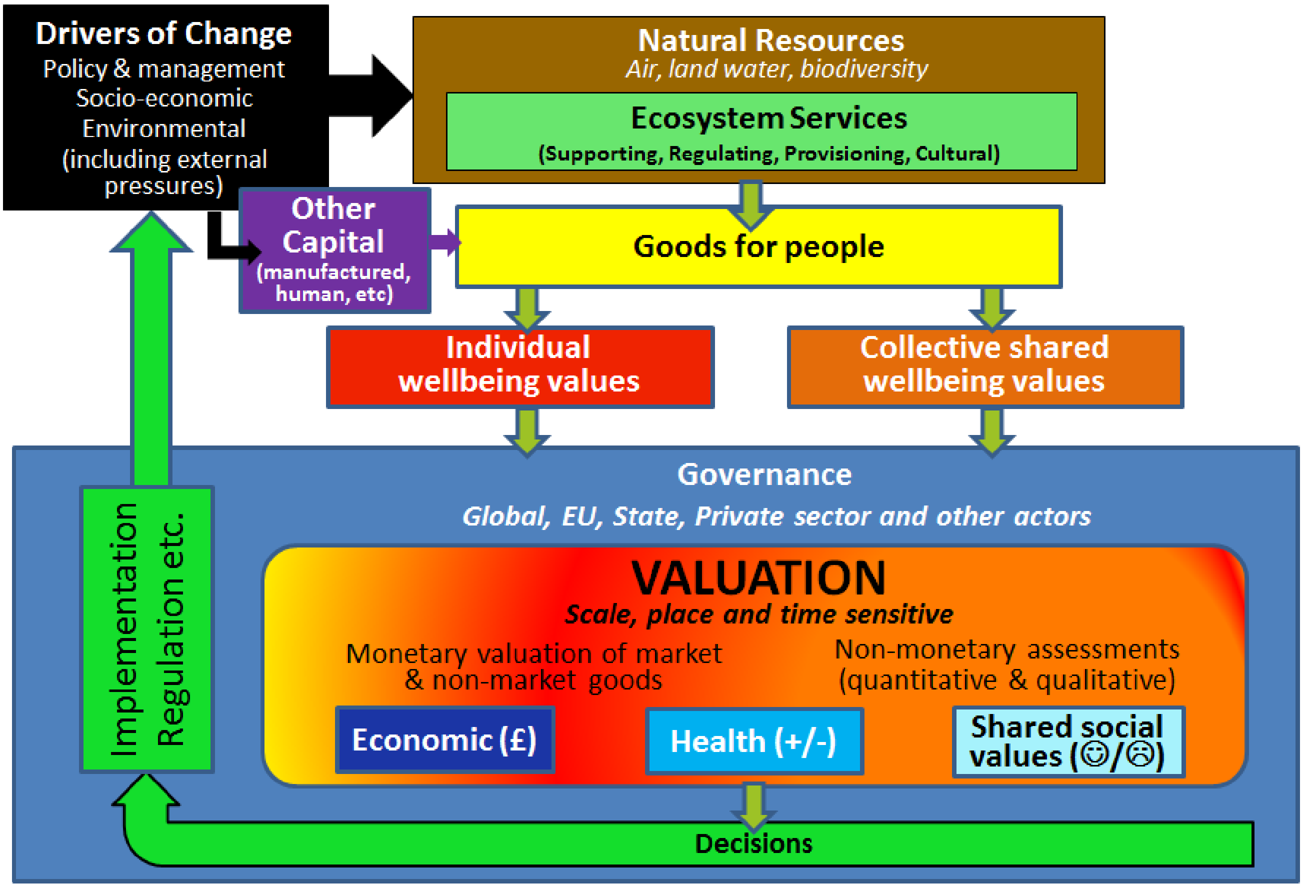
Appendix A

The four Key Challenges

1. How can the **complexity of socio-ecological systems** be incorporated into valuations of biodiversity, ecosystem services and natural resource use?
2. How can **stock sustainability** be incorporated within valuations of biodiversity, ecosystem services and natural resource use?
3. How can issues of **scale** be incorporated within valuations of biodiversity, ecosystem services and natural resource use?
4. How do we integrate natural and social science information on values for biodiversity, ecosystem services and natural resources into governance and so improve **decision-making** and implementation?

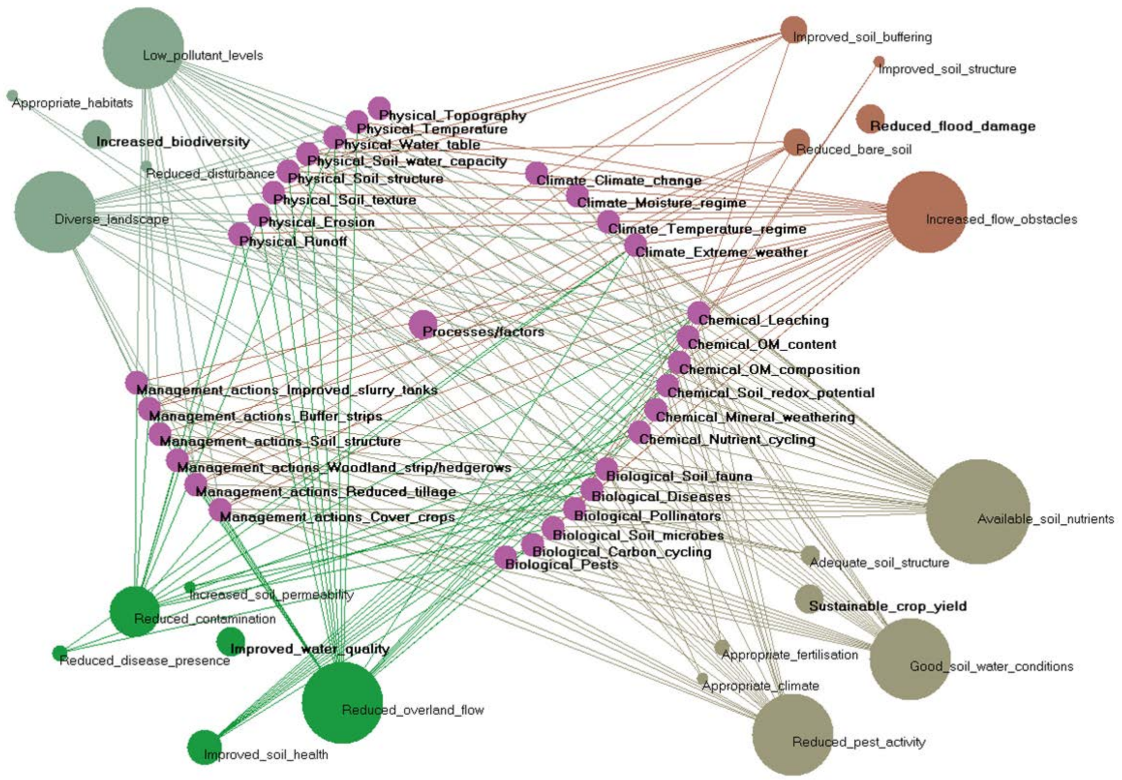
Appendix B

The conceptual framework



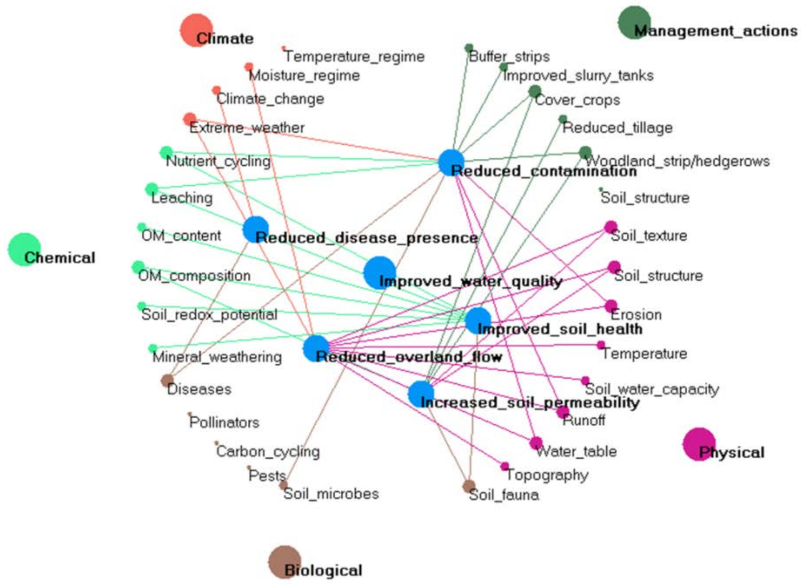
Appendix C

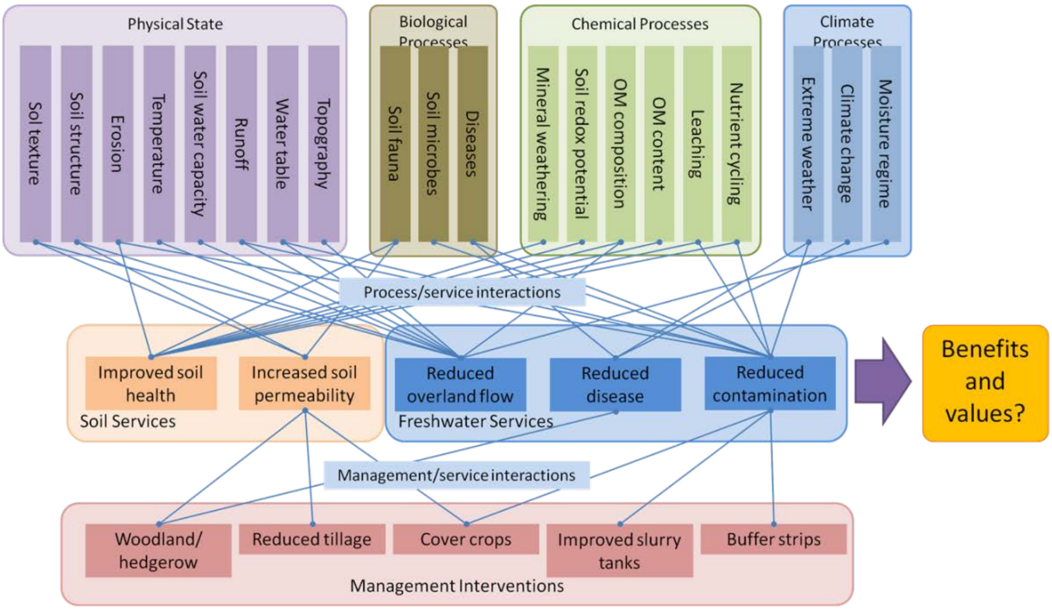
Ecosystem services and process interactions



The diagram uses the Attercap programme developed by Matt Aitkenhead (James Hutton Institute) to map links between ecosystem process (inner pink nodes together with management actions) and policy aims or final ecosystem services (outer nodes). The relative sizes of the outer nodes reflects the number of links each has. Note that these links were drawn from a workshop exercise and may not represent all possible links.

Focusing on water quality it is possible to draw a simplified network of links as illustrated in the following figures. These present the information in alternative ways. It becomes clear that we do not have information on the direct links between management and ecosystem processes and any interactions between processes.

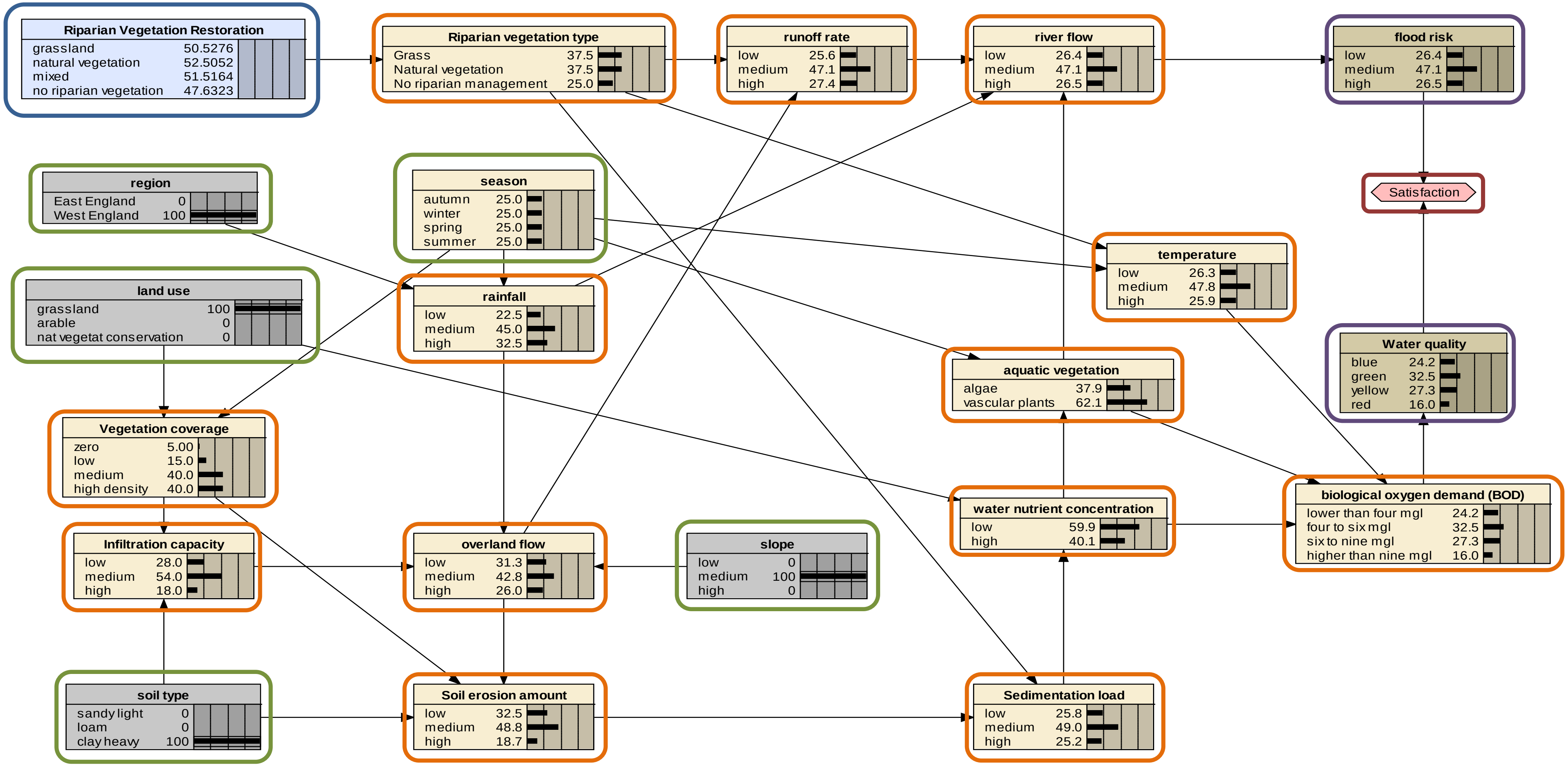




Physical State
Sol texture
Soil structure
Erosion
Temperature
Soil water capacity
Runoff
Water table
Topography
Biological Processes
Soil fauna
Soil microbes
Diseases
Chemical Processes
Mineral weathering
Soil redox potential
OM composition
OM content
Leaching
Nutrient cycling
Climate Processes
Extreme weather
Climate change
Moisture regime
Process/service interactions
Improved soil health
Increased soil permeability
Soil Services
Reduced overland flow
Reduced disease
Reduced contamination
Freshwater Services
Benefits and values?
Management/service interactions
Woodland/ hedgerow
Reduced tillage
Cover crops
Improved slurry tanks
Buffer strips
Management Interventions

Appendix D

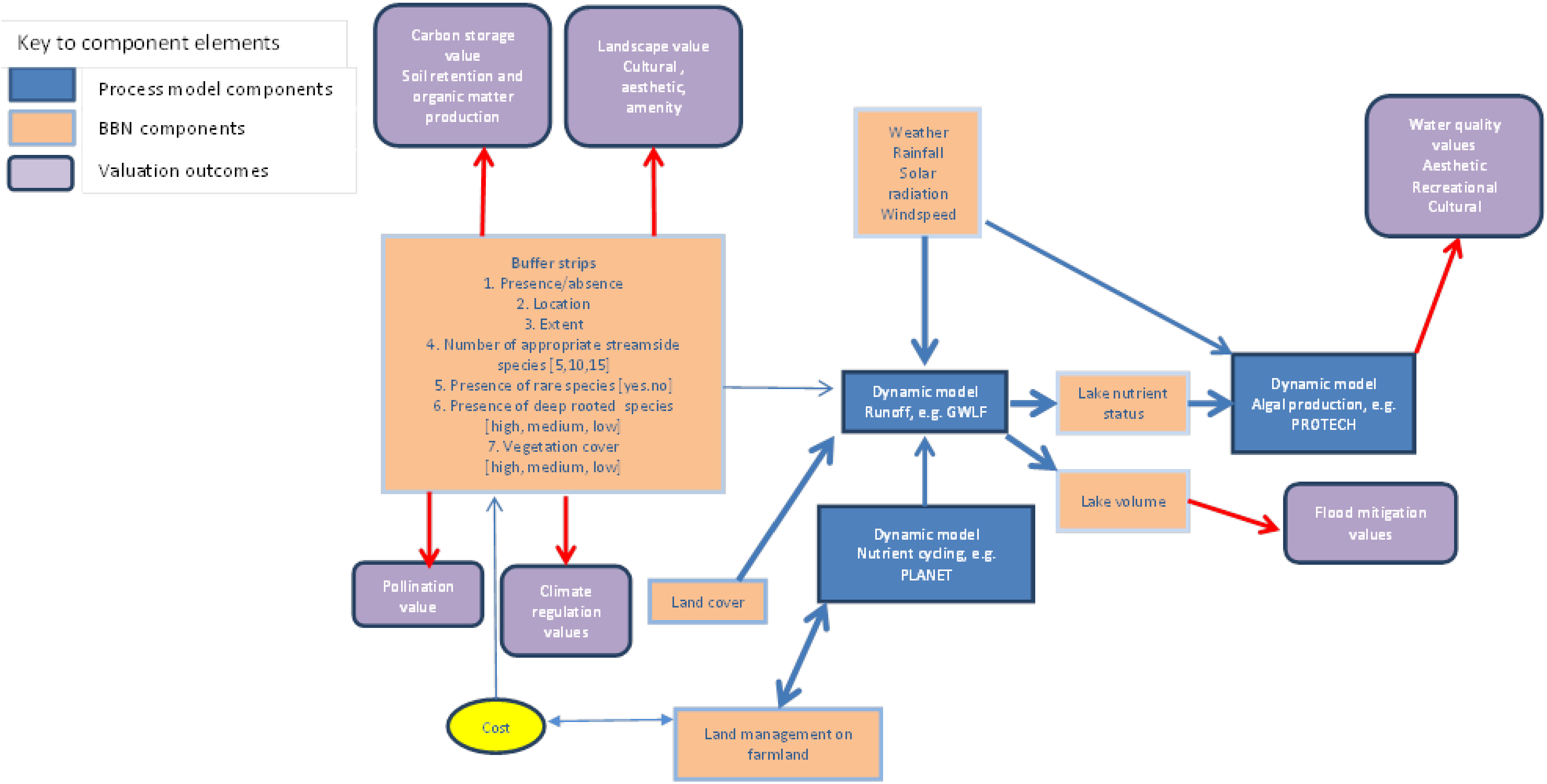
Landscape scale Bayesian Belief Network



The BBN represents the landscape model of the effects of riparian vegetation or buffer strips on water quality and flood risk. The decision node represents the management action and the values displayed indicate the 'utility' associated with each option. There are two types of state node: those without parent nodes reflect states of the system that can be set by the analyst, in this case region, season, land use, and soil type; those with parents have levels the values of which a probabilistically determined (data or knowledge based) for each combination of values taken by the parent nodes (linked by unidirectional connections). The nodes in our model represent ecosystem states, the effects of these on ecosystem processes and final ecosystem services, here represented by the state nodes . Finally there is a utility node labelled here as 'satisfaction' that represents the 'value' of the potential benefits arising from the ecosystem services. In this model we have not considered the influence of non-ecosystem capital inputs or other socio-economic factors.

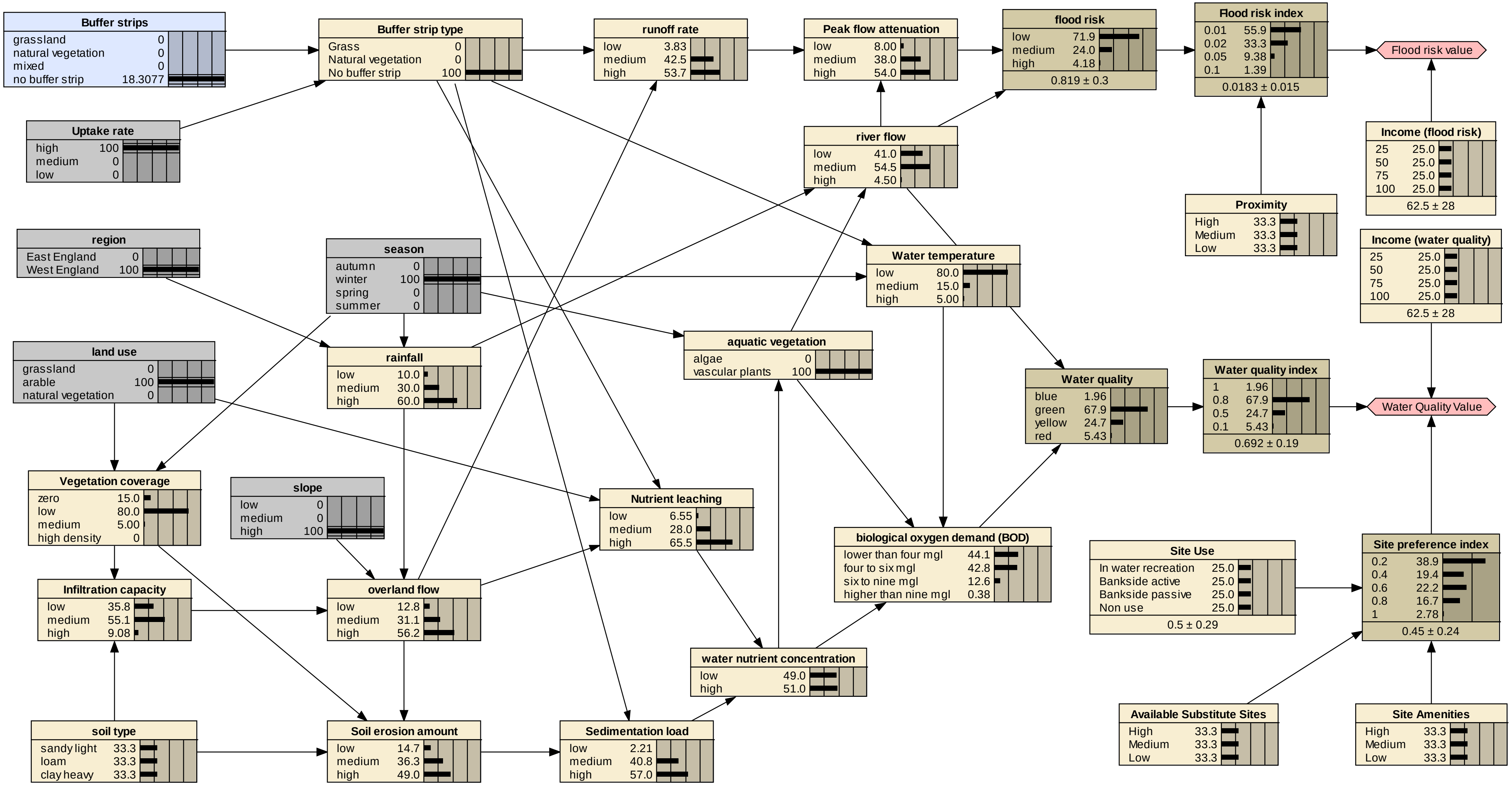
Appendix E

Catchment scale process-BBN integration

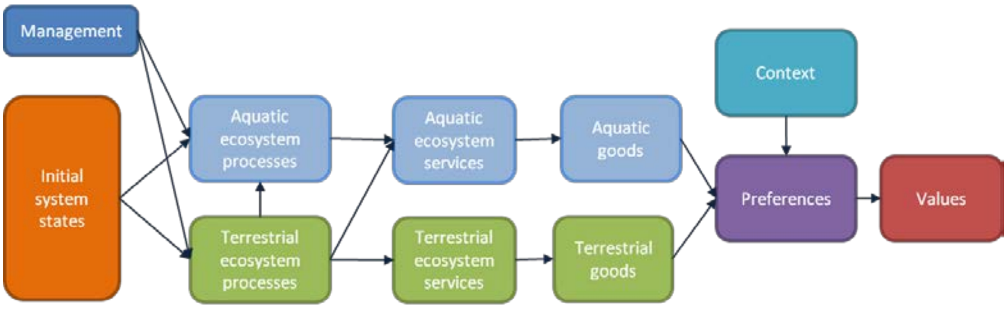


Appendix F

Landscape scale Bayesian Belief Network incorporating socio-economics



The expanded BBN incorporates both additional refinements to the bio-physical elements and new socio-economic nodes that capture influences of preferences and hence values. It is apparent that the complexity of the BBN is continually increasing and a further refinement would be to develop a series of nested models within the BBN (see below). This would allow us to maintain an overall visual simplicity with the option to expand particular submodels according to the interests and expertise of users and audiences.



Appendix G

Revised conceptual framework