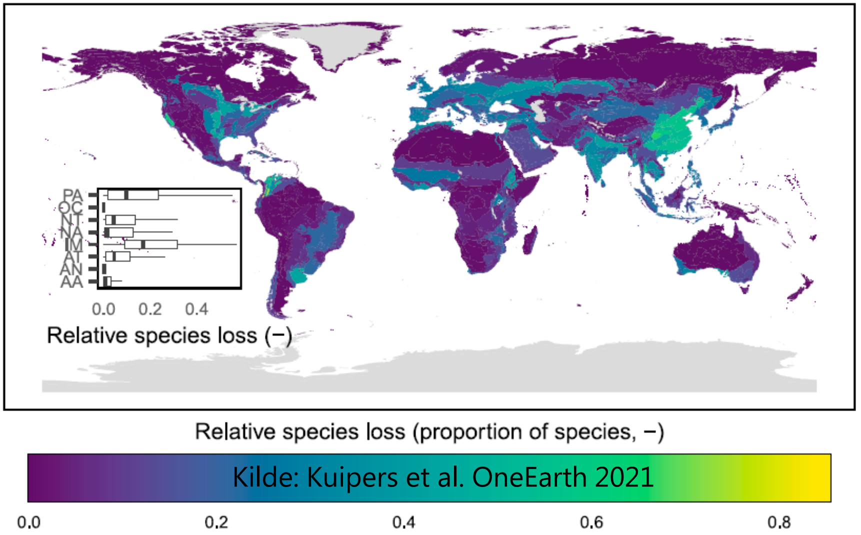
Believe in Bayes

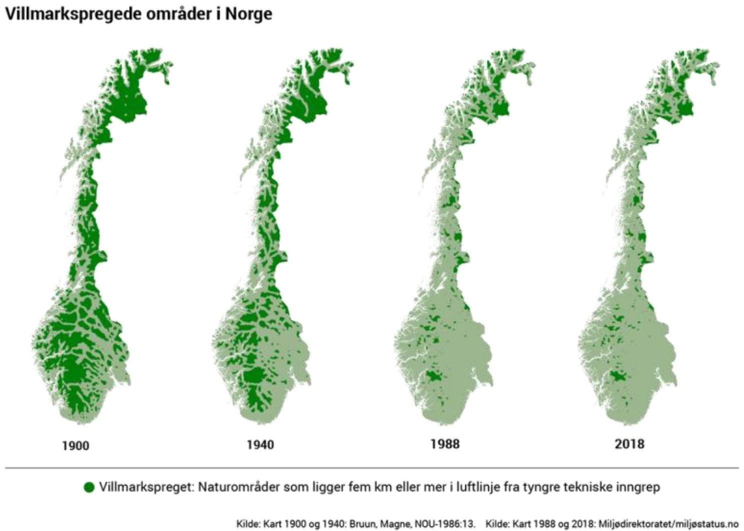
Assessing social-ecological systems, future scenarios for sustainable development using Bayesian Belief Network tools

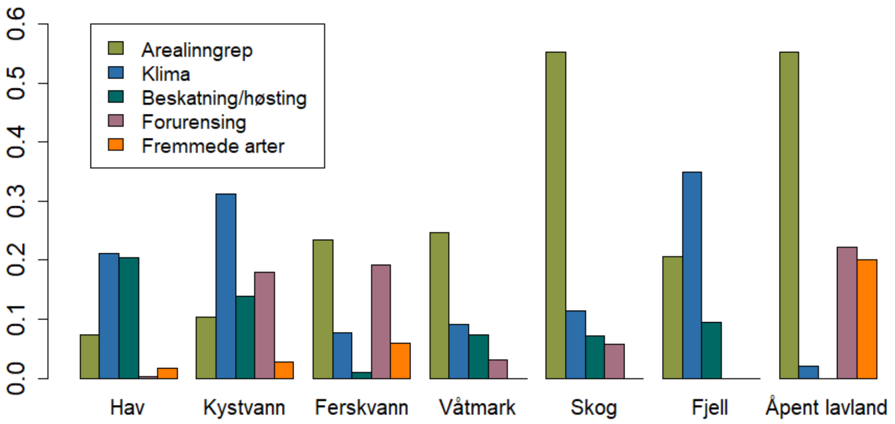
NINA
Norsk institutt for naturforskning

Land use

- Land use and land use changes, in the form of degradation, fragmentation and harvesting, are the biggest threat to biodiversity in the world. The changes in nature also affect society through the loss of ecosystem services and increased vulnerability to extreme events.







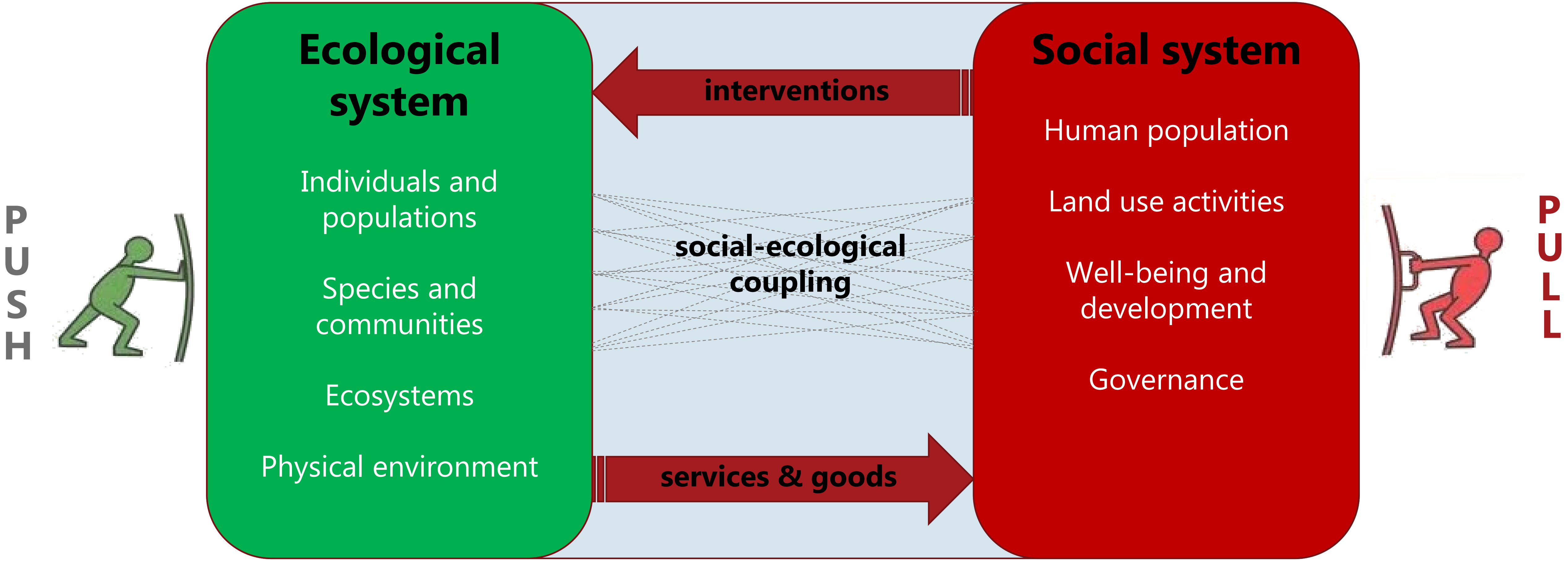
Kilde: https://www.naturindeks.no/Pressure

Landscape

- Landscapes are areas that are created through the influence of and the interplay between natural processes and human activities through the ages

human activities should be balanced in order to safeguard our and the next generation's livelihood

Social-ecological system



The challenge with natural resources

- The Arctic is undergoing the most rapid changes in the climate system worldwide
  - higher risk of extreme events
  - changes in the access to the Arctic resources
- Along the coast of Greenland, most people living in smaller settlements depend partly or entirely on hunting and small-scale fishing
  - vulnerable to the effects of climate change on natural resources and may suffer material and wellbeing deprivation
  - offering new opportunities for communities and for economic development related to exploration of natural resources
- Local ecological knowledge and scientific evidence have at times clashed, and management of Greenland's natural living resources has become highly politicised
- From this perspective, management for sustainable resource exploitation needs to build on integrated knowledge on environmental, technical, social and political characteristics

Spatial planning for future pathways

- Spatial planning is the process to balance different interests against each other to safeguard the values in the landscape for the future
  - Knowledge-driven models that can capture complex social and ecological interactions
  - Assessment of consequences of different 'what-if' scenarios in the landscape to support holistic spatial planning

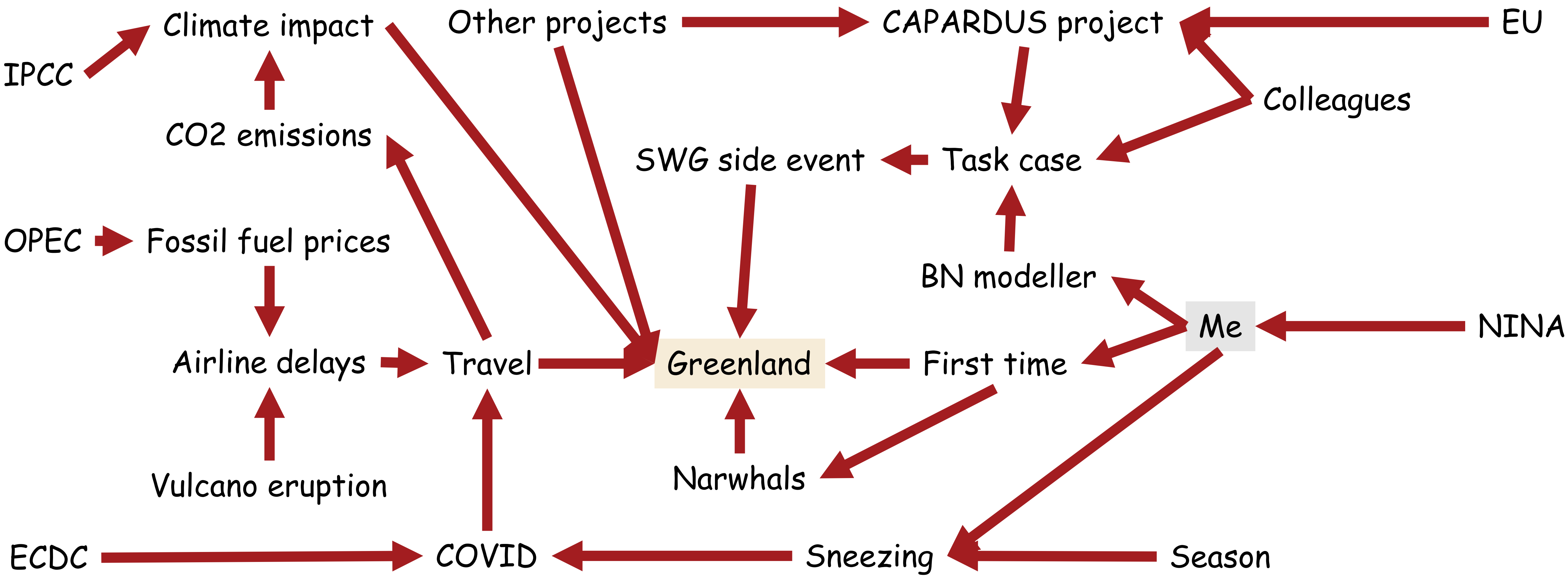
Spatial planning tools

- Novel technologies may be important for collecting and integrating data, developing knowledge-based planning and informed decision making
- One such technology is use of Bayesian Belief Network models offer the ability to explore such complex systems with limited data availability by including various forms of data – including expert knowledge and consumer preferences
- This enables policymakers and resource users to explore the outcome of various policies under different scenarios including impacts on living conditions and quality of life
- Showcase such an approach by developing a “toy model” which visualizes a real-life case for natural resource challenge focusing on inshore halibut fisheries
- Develop the online app surBayes to capture the model and stakeholder data

Bayesian Belief Networks

- A Bayesian Belief Network (BBN) provides an integrated modelling framework to structure specific scientific problems and explore future scenarios
- By explicitly addressing interactions between variables and uncertainty, BBNs provide a mechanism for graphically and probabilistically modelling the causal effects of specific management actions on the environment
- Visualization has the power to cut through the complexity and ambiguity that are often associated with politics or planning options
- Visualization concretizes possible future and stimulates engagement among stakeholders and the general public
- Geographic Information Systems (GIS) to visualize the spatial consequences of scenarios in the landscape

Why am I here?


Climate impact
Other projects
CAPARDUS project
EU
IPCC
Colleagues
CO2 emissions
SWG side event
Task case
OPEC
Fossil fuel prices
BN modeller
Me
NINA
Airline delays
Travel
Greenland
First time
Vulcano eruption
Narwhals
ECDC
COVID
Sneezing
Season

How to construct a BBN

1. Construct the network with important social and environmental factors (nodes) and their interactions (edges)
2. Assign possible alternative states of the different factors
3. Survey beliefs and/or include data
4. Optional: link to Geographic Information Systems (GIS) to visualize spatial effects
5. Infer model outputs and adjust its factors to assess consequences of decisions

surBayes

Dashboard

- Home
- Instructions
- Construct network
- Define nodes
- Enter data
- Inference

Network input

- Create new model
- Load exising model

Choose a file

Halibut

Password:

••••••••

Load!

Network correctly loaded...

Save!

Instructions

Welcome to the **surBayes** application to construct, learn and infer discrete Bayesian Belief Network models in a web-based rendering interface. The applications includes the following components:

The first step is to choose either to create a new model or load an existing one in the left-hand sidepanel in the **Network input** box. Enter the new model name or choose an existing model, enter an optional password and press *Load!* Any changes made in the remainder of the application are only saved to the database when pressing the *Save!* button. When no password is given, the model will be public available.

Once a model has been created or loaded, the model structure can be constructed by choosing the **View/Edit** menu. The *View/Edit* button allows you to visialize and edit the network. In the graphical display, the structure can be edited using the EDIT button. In case groups of nodes have been identified under the next step, these can be highlighted with the checkbox *Show Groups.* Remember to save edits using the *Save edits* button. Once satisfied with the network structure, this can be finalized by pressing the *Finalize!* button after which changes are not possible anymore.

An overview over the nodes in the network can be viewed by choosing the **Define nodes** menu and pressing the *View / Edit* button. By entering group definitions (semicolon separated) into the textbox, these can be added to the different nodes in the table. In the table, after having finalized the network structure, also the node states can be added (semicolon separated). Edits can be saved by pressing the *Save edits* button. Once satisfied with the network structure, this can be finalized by pressing the *Finalize!* button after which changes are not possible anymore.

Once the network structure and nodes have been finalized, the data for the network can be collected in the **Enter data** menu. By pressing the *Load overview* button, a tabular overview of the nodes and whether they have conditional probability tables (CPT) connected to them. Individual evidences of the states of the nodes can be obtained either by pressing the *Survey evidences* button or uploading an Evidences Data file (CVS, semicolon delimited). Belief data for each node can be collected by choosing a (group and) node, and either pressing the *Survey beliefs* button to perform a choice survey or entering the required data directly into the CPT tables by pressing the *View / Edit* button. Edits can be saved to the table by pressing the *Save edits* button.

Once network structure, nodes and data are in place, the **Inference** menu allows visualizing the model outcomes. The network structure can be visualized by pressing the *Display network* button. Also, the characteristics of the nodes in the network can be visualized by pressing the *Display nodes* button. After having chosen a node of interest in the dropdown menu, also the probability distribution for single nodes can be plotted by pressing the *Display probability* button, either with or without including a node of influence in the plot. Which nodes have the most influence on the choosen node of interest can be visualized by pressing the *Display influencers* button. To assess various 'what-if' scenarios, evidence can be set by pressing the *Add evidence* button. In the tabular overview over nodes, the state of various nodes can be set. By pressing the *Submit* button, these changes are applied. Renewing the displays show the adjusted outcomes. The network can be returned to its default by clicking the *Reset evidence* link. Finally, in case the network includes a temporal component including an input node (no parents) and output node (no childs) that have the same meaning and states, these can be chosen from the dropdown menu, including also a node of interest to plot, and after setting the number of time steps (a number between 1 and 10) the temporal changes to the node of interest will be visualized by pressing the *Display temporal* button.

The **surBayes** application includes two example Bayesian Belief models. ServiceScape is (a discretized version of) a model for wildlife-related ecosystem services in the Greater Serengeti-Mara Ecosystem link to paper developed within the AfricanBioServices project, funded by the EU. The spatially-explicit output from this model is visualized at ServiceScape. The second example model on Halibut fisheries in Greenland was developed as part of the CAPARDUS project, also funded by the EU.

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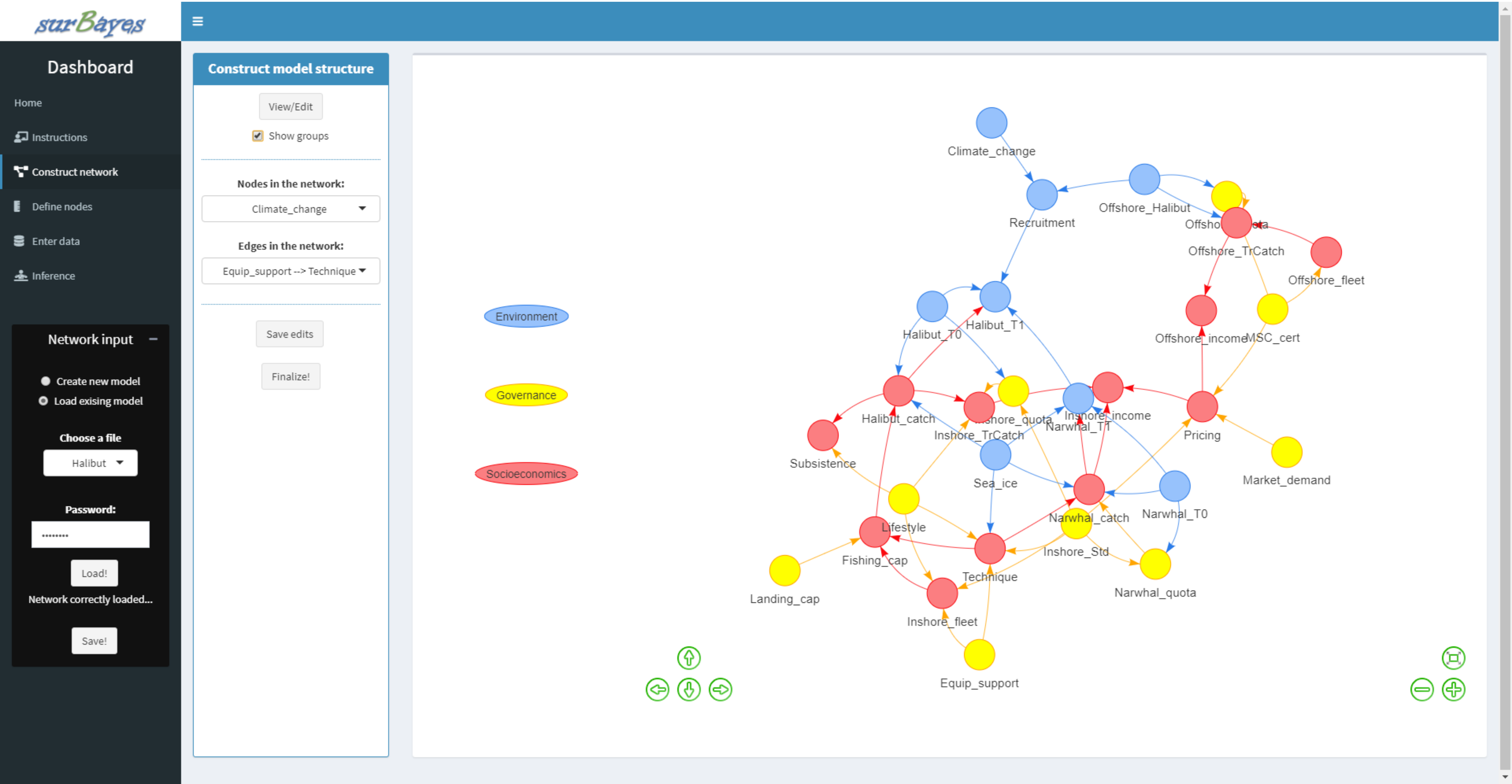

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surBayes

Dashboard

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Network input

Create new model

Load exising model

Choose a file

Halibut

Password:

Load!

Network correctly loaded...

Save!

Define node characteristics

Enter groups:

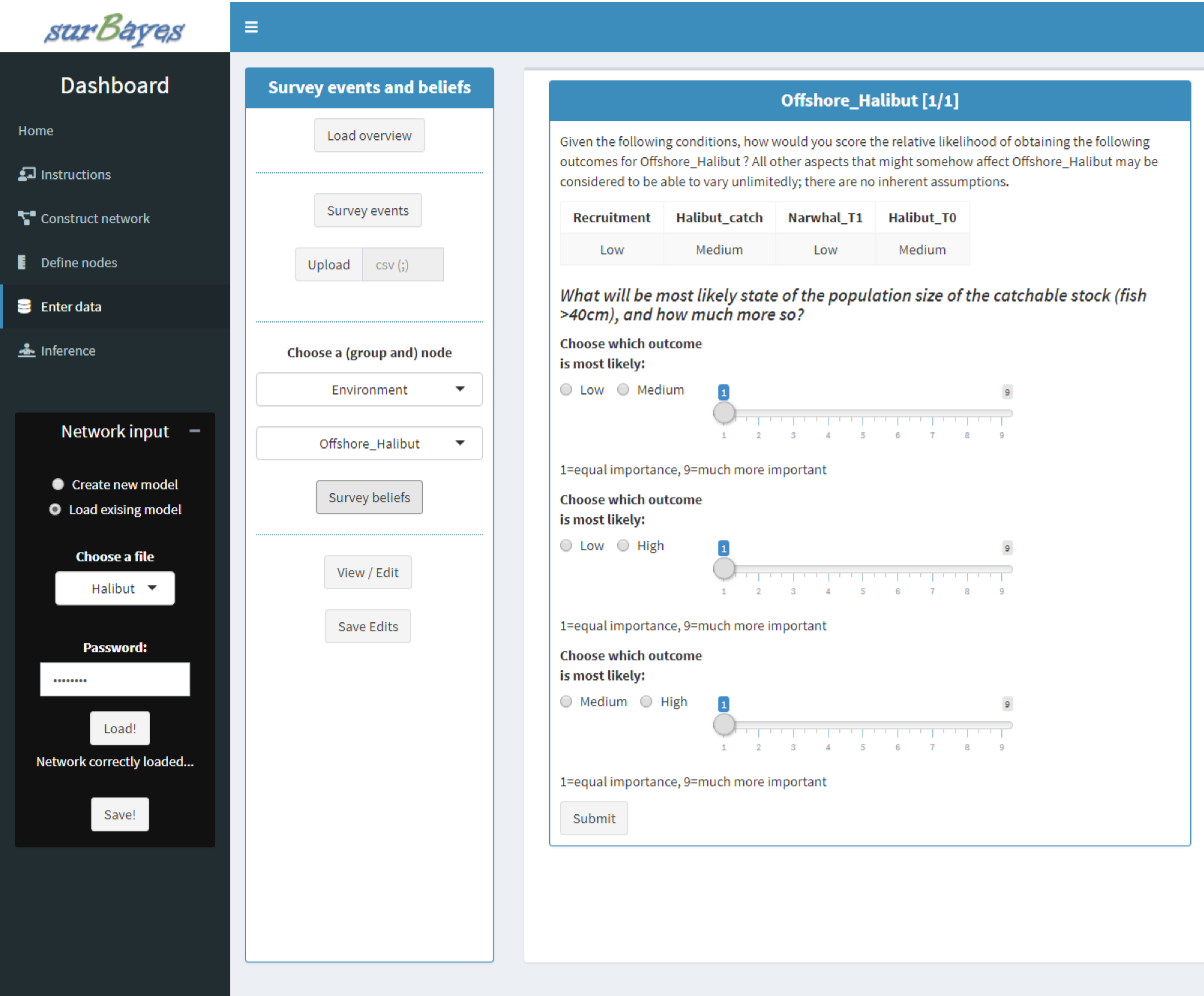
Semicolon separated

View / Edit

Save edits

Finalize!

ProjID	Group	Name	Description	States	N_states	N_parent	N_child
0	Environment	Climate_change	the long-term effect of climate change to halibut populations	Negative;Negligible;Positive	3	0	1
0	Governance	Equip_support	the company-based subsidies and public loans	No;Yes	2	0	2
0	Socioeconomics	Fishing_cap	the total catch capacity	Low;Medium;High	3	3	1
0	Socioeconomics	Halibut_catch	the total weight of halibut caught inshore	Low;Medium;High	3	3	3
0	Environment	Halibut_T0	the population size of the catchable stock (fish >40cm) at the start of a 7-year period	Low;Medium;High	3	0	3
0	Environment	Halibut_T1	the population size of the catchable stock (fish >40cm) at the end of a 7-year period	Low;Medium;High	3	4	0
0	Socioeconomics	Inshore_fleet	the number of people engaged in fishing/hunting	Low;Medium;High	3	3	1
0	Socioeconomics	Inshore_income	the household income derived from fishing, hunting or other (undefined activities)	Fishing;Hunting;Other	3	3	0
0	Governance	Inshore_quota	the total weight of halibut allowed to be caught inshore	Low;Medium;High	3	2	1
0	Governance	Inshore_Std	the political balance between sustainability and income and provision self-suffiency	No;Yes	2	0	5
0	Socioeconomics	Inshore_TrCatch	the total weight of inshore halibut traded	Low;Medium;High	3	3	1
0	Governance	Landing_cap	the presence of landing facilities in the community	No;Yes	2	0	1
0	Governance	Lifestyle	the proportion of the households engaged as occupational or recreational fishermen	Occupational;Recreational;Non-resource	3	0	4
0	Governance	Market_demand	the external market influence on pricing	Low;Medium;High	3	0	1
0	Governance	MSC_cert	the MSC certification practice, where sustainable harvest and no environmental damage is required	No;Yes	2	0	3
0	Socioeconomics	Narwhal_catch	the number of narwhal caught	Low;Medium;High	3	4	2
0	Governance	Narwhal_quota	the total number of narwhal allowed to be caught inshore	Low;Medium;High	3	2	1
0	Environment	Narwhal_T0	the number of narwhal in the population at start of a 7-year period	Low;Medium;High	3	0	3
0	Environment	Narwhal_T1	the number of narwhal in the population at the end of the 7-year period	Low;Medium;High	3	3	1
0	Socioeconomics	Offshore_fleet	the total tonnage of trawlers	Low;Medium;High	3	1	1
0	Environment	Offshore_Halibut	the population size of the catchable stock (fish >40cm)	Low;Medium;High	3	0	3
0	Socioeconomics	Offshore_income	the number of household incomes that are derived from offshore fisheries	Low;Medium;High	3	2	0
0	Governance	Offshore_quota	the total weight of halibut allowed to be caught offshore	Low;Medium;High	3	2	1
0	Socioeconomics	Offshore_TrCatch	the total weight of offshore halibut traded	Low;Medium;High	3	3	1
0	Socioeconomics	Pricing	the per weight prices agreed upon through international negociations	Low;Medium;High	3	3	2
0	Environment	Recruitment	the effect of 1-year old offshore survival to the inshore catchable stock seven years later	Low;Medium;High	3	2	1
0	Environment	Sea_ice	the sea ice conditions, measured in number of months covered per year	Fixed_ice;Slush_ice;Ice_free	3	0	4
0	Socioeconomics	Subsistence	the contribution to the household subsistence	Low;Medium;High	3	2	0
0	Socioeconomics	Technique	the distribution of harvest techniques/vehicles used in fishing/hunting activities	Ice-based;Dinghy;Cutter	3	4	2



Capture stakeholder knowledge and beliefs through node-specific online surveys

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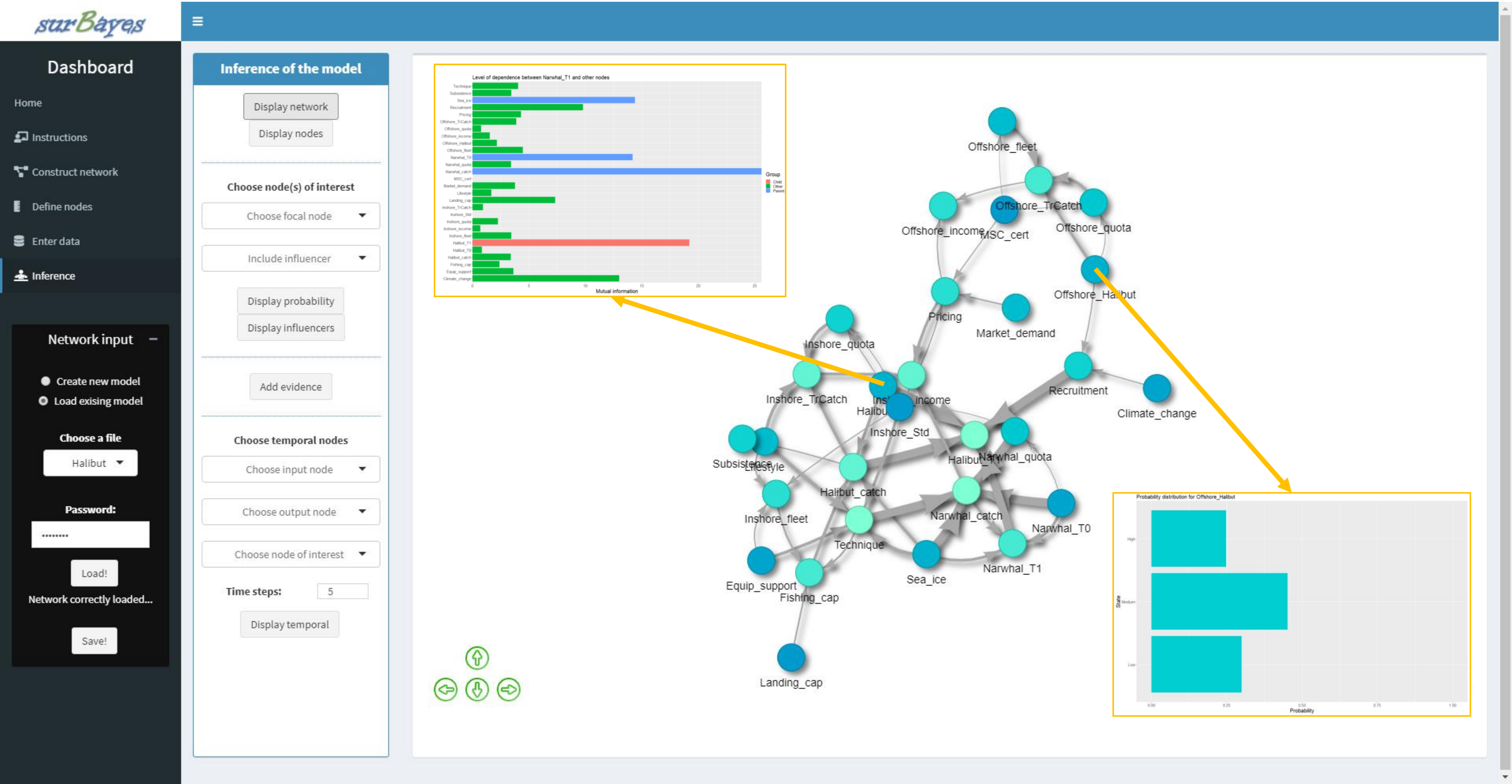

Cooperation and expertise for a sustainable future

Foto. A. Staverløkk