Using *Mental Modeler* to measure conceptual change of social-ecological systems

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MentalModeler v0.2

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www.mentalmodeler.org

MentalModeler

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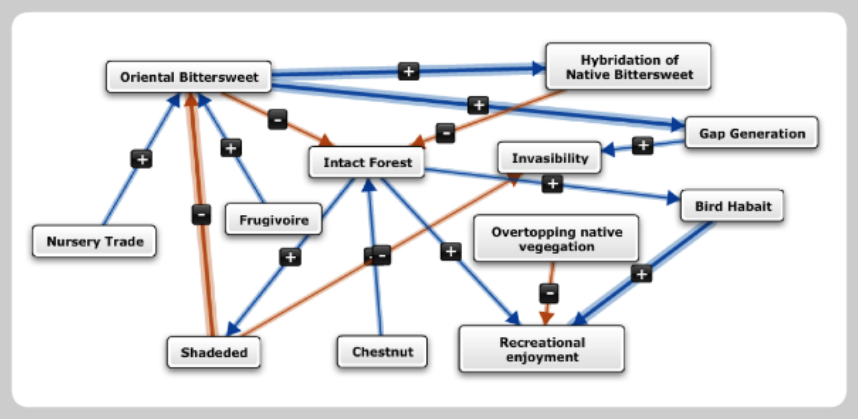
01 HOME

What is *Mental Modeler*?

Mental Modeler is modeling software that helps individuals and communities capture their knowledge in a standardized format that can be used for scenario analysis.



Based in Fuzzy-logic Cognitive Mapping (FCM), users can easily develop semi-quantitative models of environmental issues, social concerns or social-ecological systems in *Mental Modeler* by:

- Defining the important components of a system
- Defining the relationships between these components
- Running "what if" scenarios to determine how the system might react under a range of possible changes.

Fuzzy Cognitive Mapping (FCM)

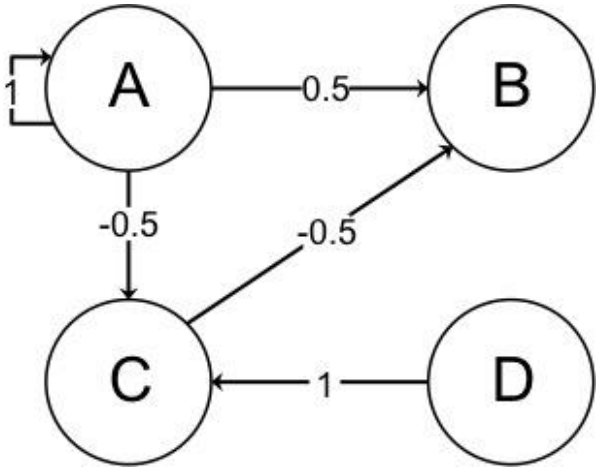
A **Fuzzy cognitive map** is a cognitive map within which the relations between the elements (e.g. concepts, events, project resources) of a "mental landscape" can be used to compute the "strength of impact" of these elements.

Fuzzy cognitive maps are signed fuzzy digraphs.

Spreadsheets or tables are used to map FCMs into matrices for further computation

Reliant on fuzzy logic AND cognitive mapping

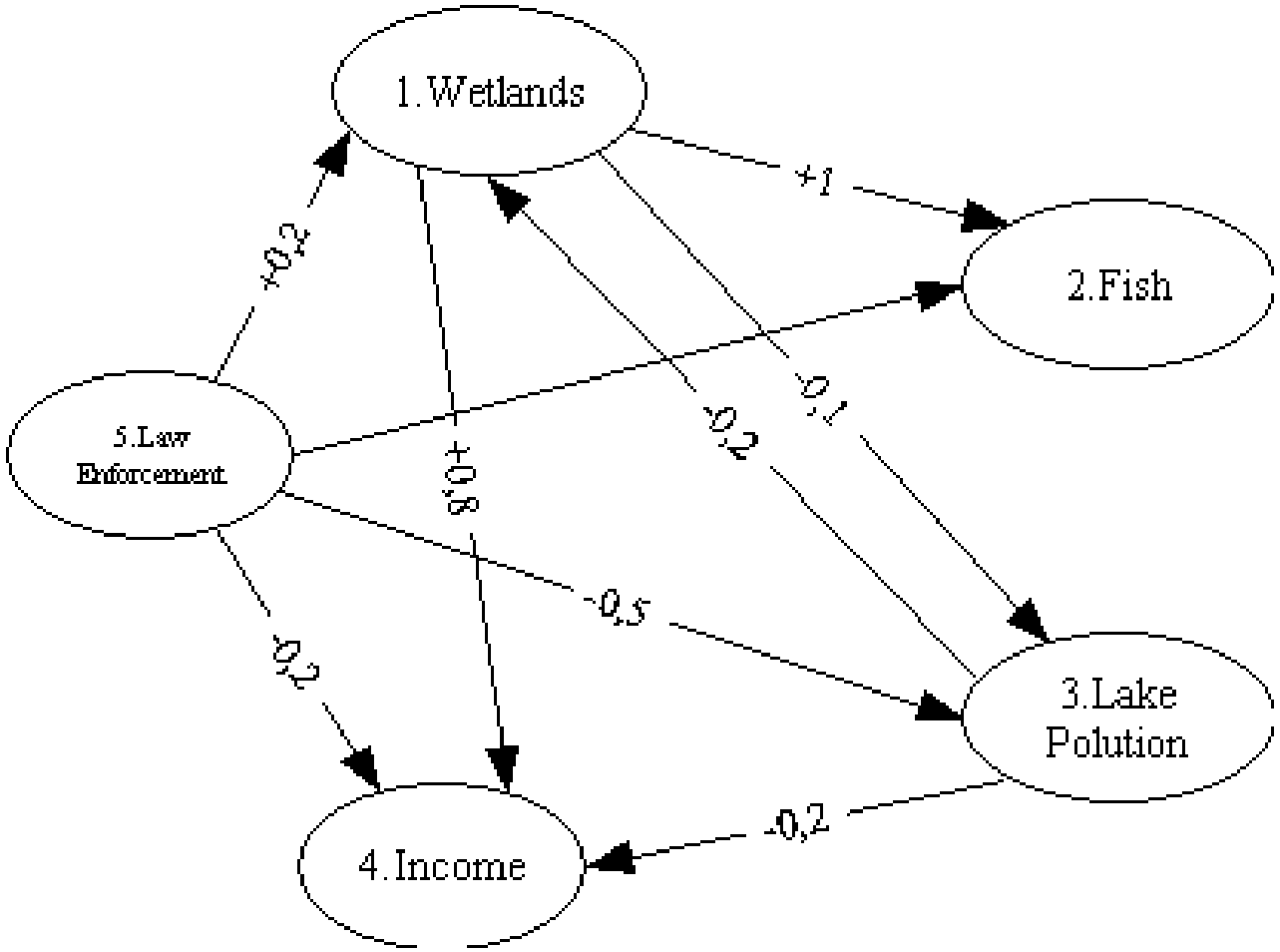
Bart Kosko
Professor, USC



How to construct a FCM?

- A **Fuzzy cognitive map** is a special kind of cognitive/concept map within which the components and relationships between the components are defined in specific ways.
  - **Components** in a fuzzy-logic cognitive map need to be defined as things that can go increase or decrease (like precipitation, animal populations, satisfaction, hunger, or traffic)
  - **Relationships** in an fuzzy-logic cognitive map have 2 main characteristics: (a) the direction of a relationship (which way the arrow is pointing) and (b) the degree of influence one component can have on another (positively or negatively) parameterized between a fuzzy set from 0 and 1.

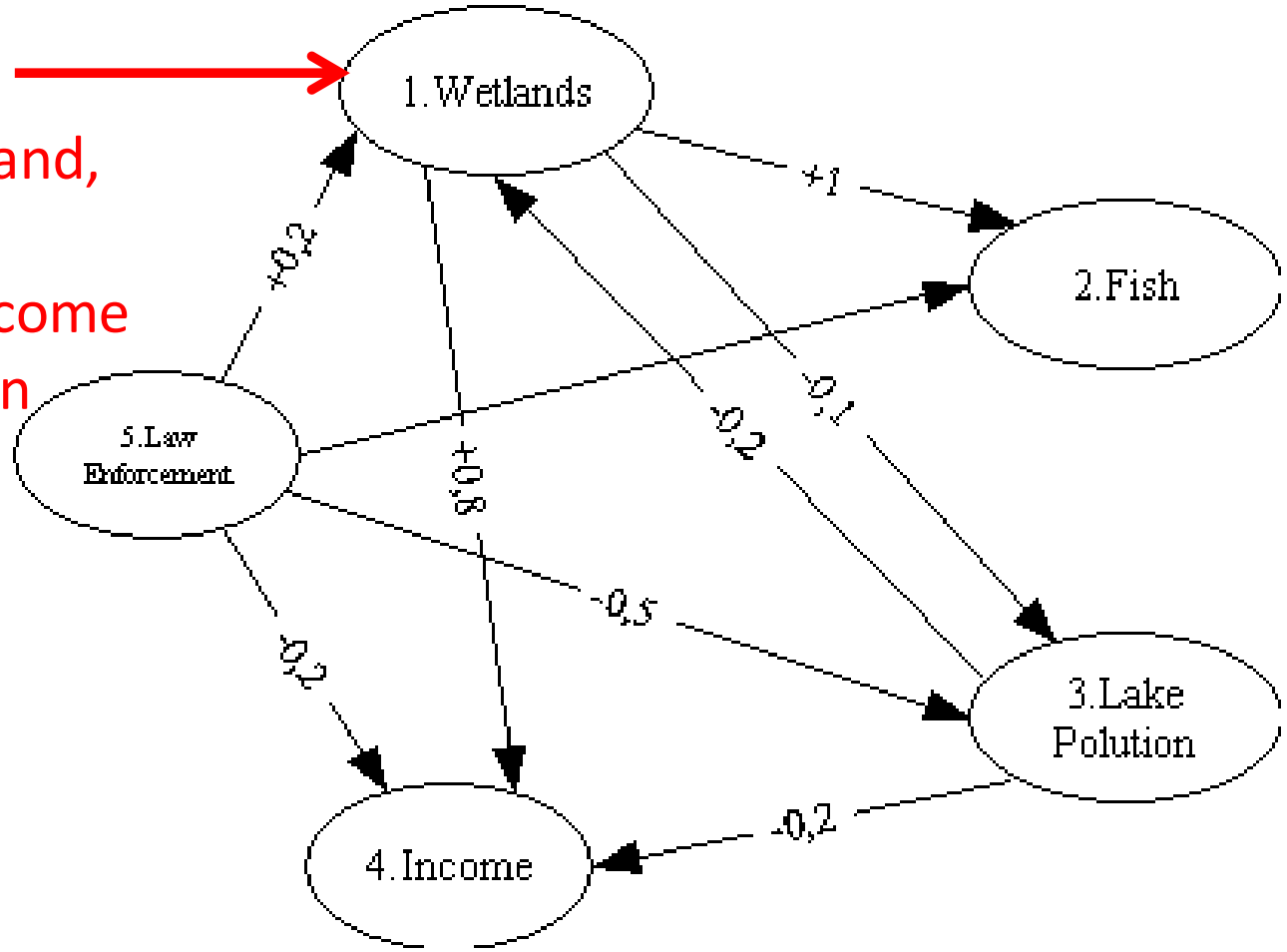
Example


1.Wetlands
2.Fish
3.Lake Polution
4.Income
5.Law Enforcement
+1
+0,2
+0,8
-0,2
-0,1
-0,5
-0,2
-0,2

Example

Components

The amount of wetland, the amount of law enforcement and income can all go up or down



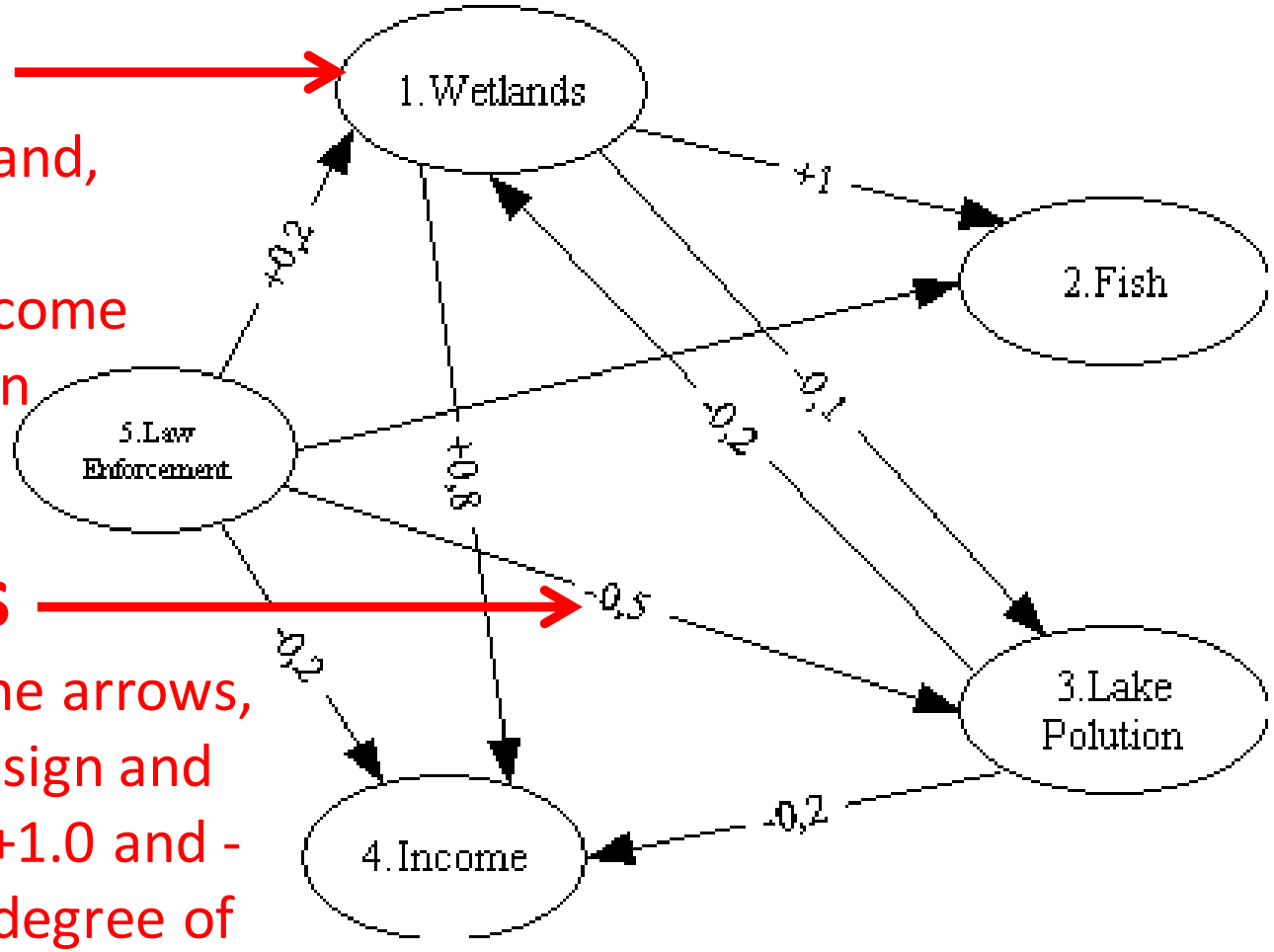
Example

Components

The amount of wetland, the amount of law enforcement and income can all go up or down

Relationships

These direction of the arrows, positive or negative sign and numbers (between +1.0 and -1.0) all indicate the degree of influence one component can have on another

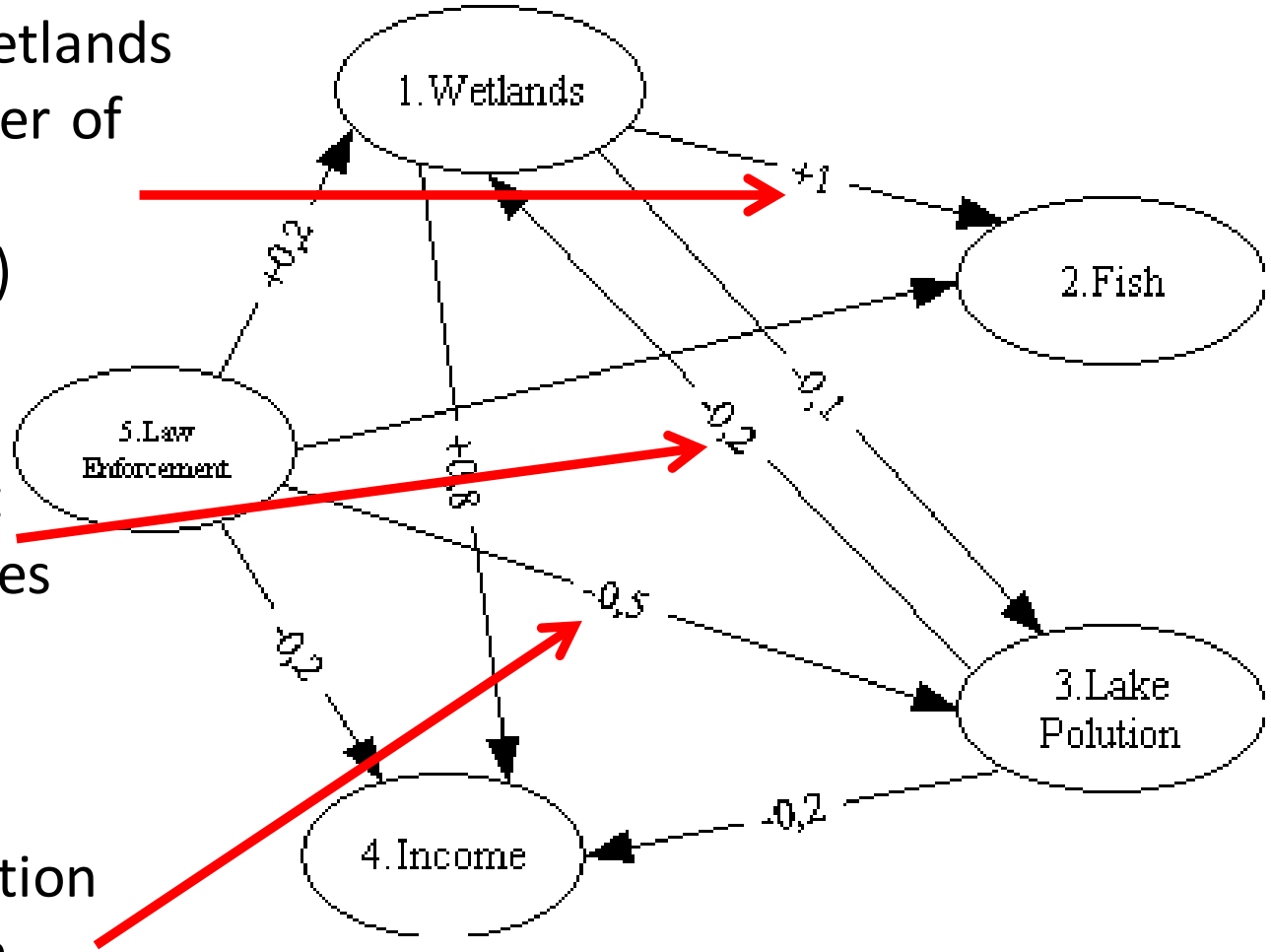


Thinking about relationships

As the amount of wetlands increases, the number of fish increases a lot (indicated by the +1)

As lake pollution increases, the amount of wetlands decreases slightly (-0.2)

As law enforcement increases, lake pollution decreases a medium amount (+0.5)



Rule of Thumb for Relationships

When determining the relationships between components in an FCM always ask yourself 2 questions:

1. When this component increases, does the other component increase or decrease?
2. Is it a high increase/decrease, medium increase/decrease or low increase/decrease?

How can you analyze an FCM?

What are they good for?

- Calculating Structural Network Metrics

  --Measuring and representing knowledge (and variation)

  --Determining driving variables and sensitive variables and common belief structures

What are they good for?

- Calculating Structural Network Metrics

  --Measuring and representing knowledge (and variation)

  --Determining driving variables and sensitive variables and common belief structures

- Calculating Scenario (Functional) Analysis

  -- Understanding how stakeholders anticipate the impacts of environmental change

  -- Decreasing uncertainty associated with environmental change

Knowledge Structure

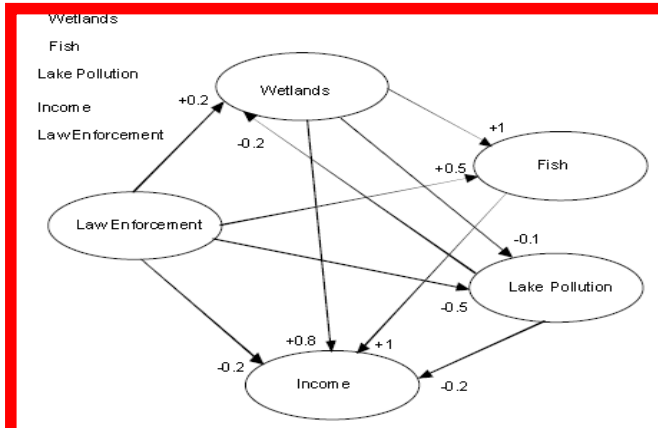


Fig. 3. Example fuzzy cognitive map.

Cognitive Maps collected can then be translated into a matrix format for analyses

	1.Amount of wetland	2. Fish Population	3. Pollution	4. Livelihood	5. Laws
1. Amount of wetland	0	1	-0.1	0.8	0
2. Fish Population	0	0	0	1	0
3. Pollution	-0.2	-1	0	-0.2	0
4. Livelihood	0	0	0	0	0
5. Laws	0.2	0.5	-0.5	-0.2	0

Mental Model Structural Measurement	Description of Measure and Cognitive Inference
N (Concepts)	Number of variables included in model; higher number of concepts indicates more components in the mental model (Özesmi and Özesmi 2004)
N (Connections)	Number of connections included between variables; higher number of connections indicates higher degree of interaction between components in a mental model (Özesmi and Özesmi 2004)
N (Transmitter)	Components which only have "forcing" functions; indicates number of components that effect other system components but are not affected by others (Eden et al.1992)
N (Receiver)	Components which have only receiving functions; indicates the number of components that are affected by other system components but have no effect (Eden et al.1992)
N (Ordinary)	Components with both transmitting and receiving functions; indicates the number of concepts that influence and are influenced by other concepts (Eden et al.1992)

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$$\mathrm{od}(v_i) = \sum_{k=1}^{N} \bar{a}_{ik}$$

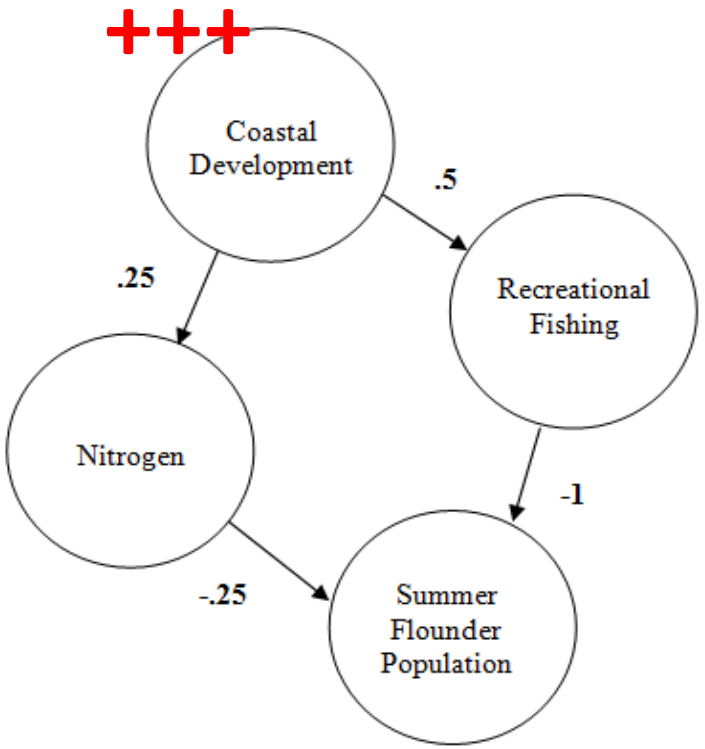
$$\mathrm{id}(v_i) = \sum_{k=1}^{N} \bar{a}_{ki}$$

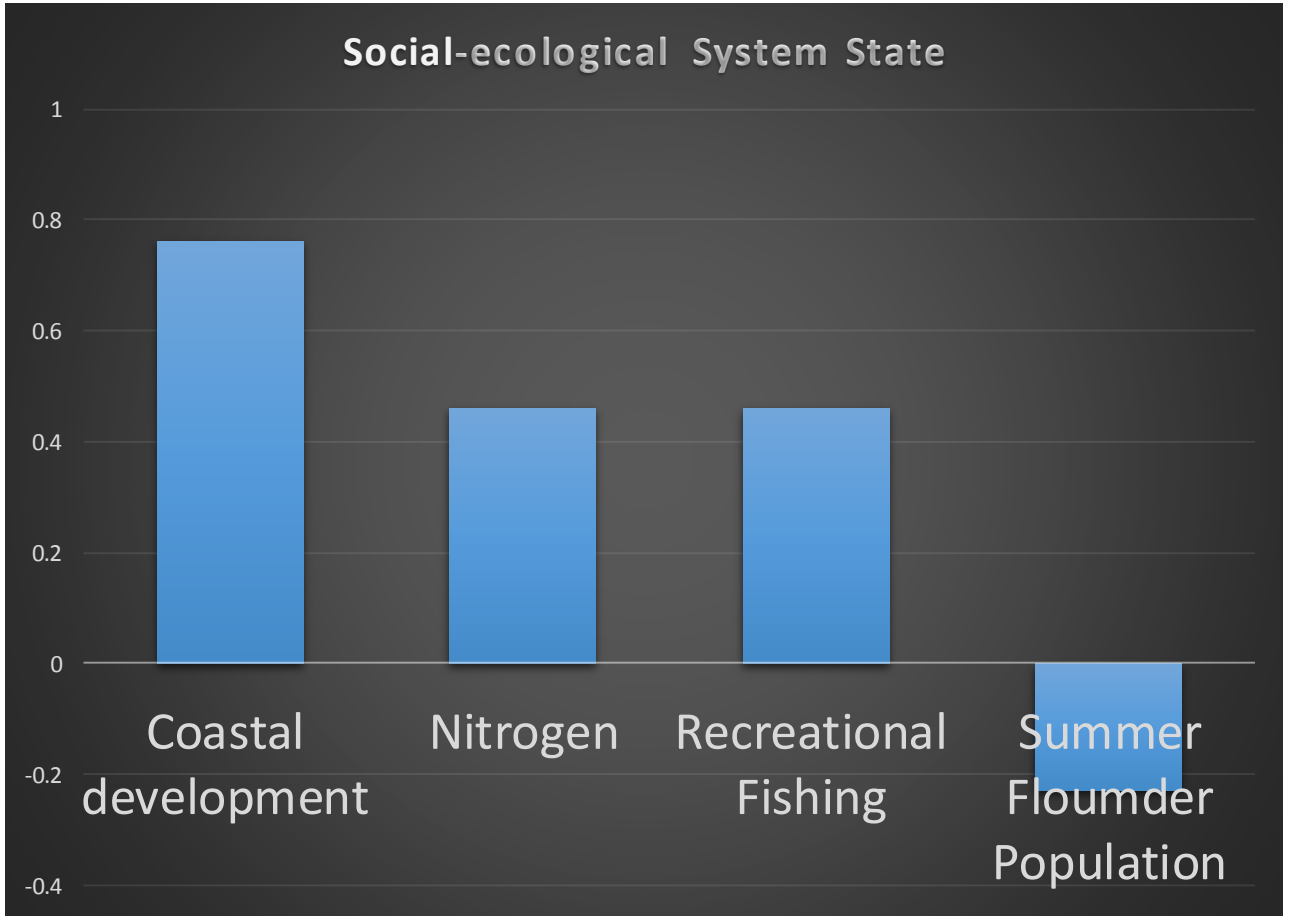
Mental Model Structural Measurement	Description of Measure and Cognitive Inference
Centrality	Absolute value of either (a) overall influence in the model (all + and – relationships indicated, for entire model) or (b) influence of individual concepts as indicated by positive (+) or negative (-) values placed on connections between components; indicates (a) the total influence (positive and negative) to be in the system or (b) the conceptual weight/importance of individual concepts (Kosko 1986a). The higher the value, the greater is the importance of all concepts or the individual weight of a concept in the overall model
C/N	Number of connections divided by number of variables (concepts). The lower the C/N score, the higher the degree of connectedness in a system (Özesmi and Özesmi 2004)
Complexity	Ratio of receiver variables to transmitter variables. Indicates the degree of resolution and is a measure of the degree to which outcomes of driving forces are considered. Higher complexity indicates more complex systems thinking (Eden et al.1992; Özesmi and Özesmi 2004)
Density	Number of connections compared to number of all possible connections. The higher the density, the more potential management polices exist (Özesmi and Özesmi 2004; Hage and Harary 1983)
Hierarchy Index	Index developed to indicate hierarchical to democratic view of the system. On a scale of 0-1, indicates the degree of top-down down (score 1) or democratic perception (score 0) of the mental model (McDonald 1983)

$$D = \frac{C}{N(N-1)}$$

$$h = \frac{12}{(N-1)N(N+1)} \sum_i \left[\frac{\mathrm{od}(v_i) - \left(\sum \mathrm{od}(v_i)\right)}{N} \right]^2$$

Scenario Analysis





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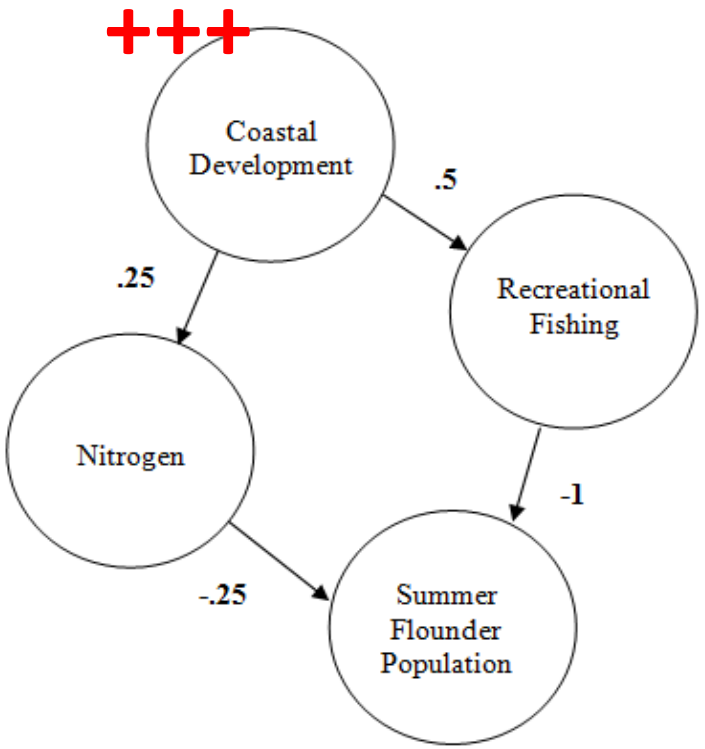
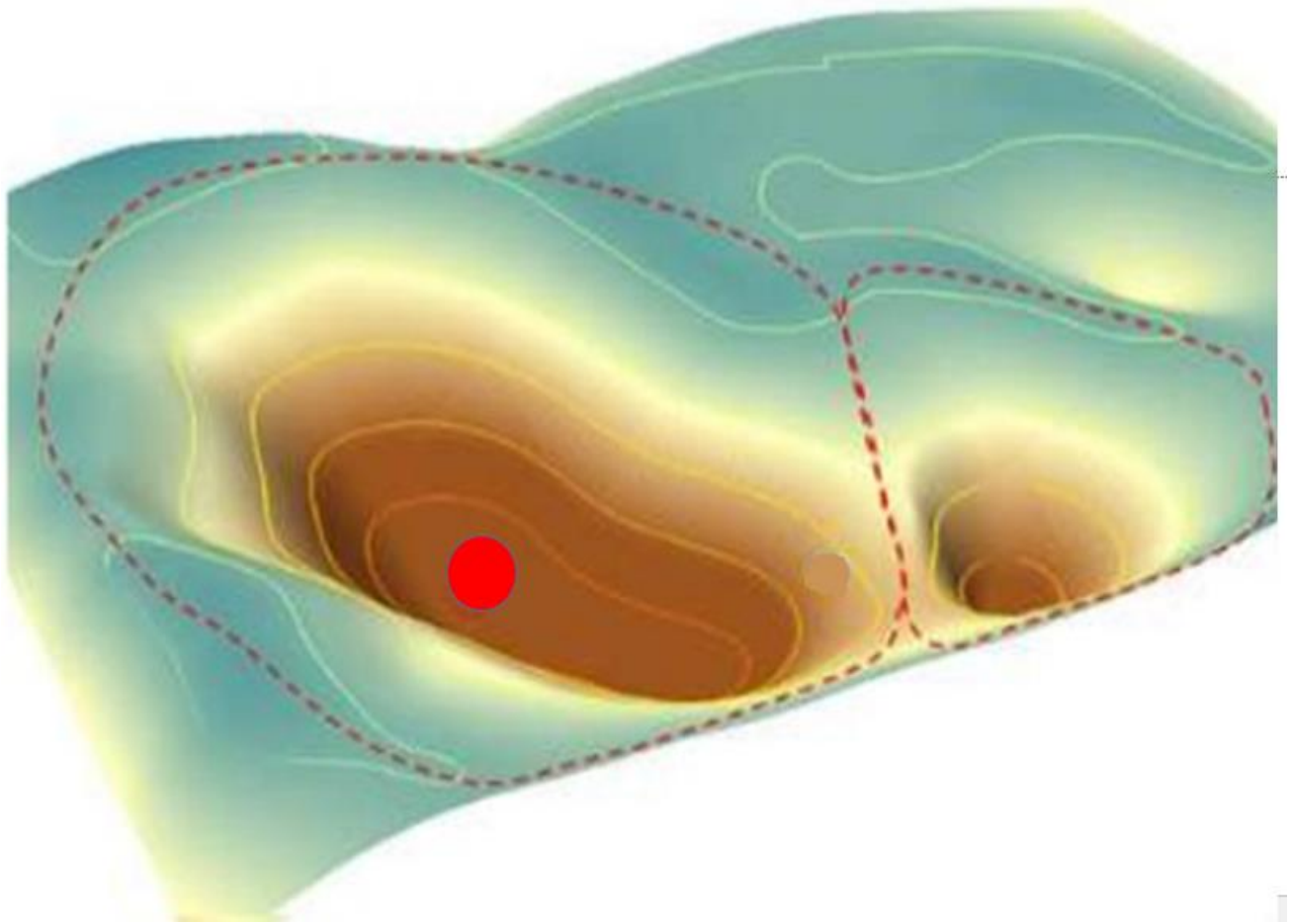
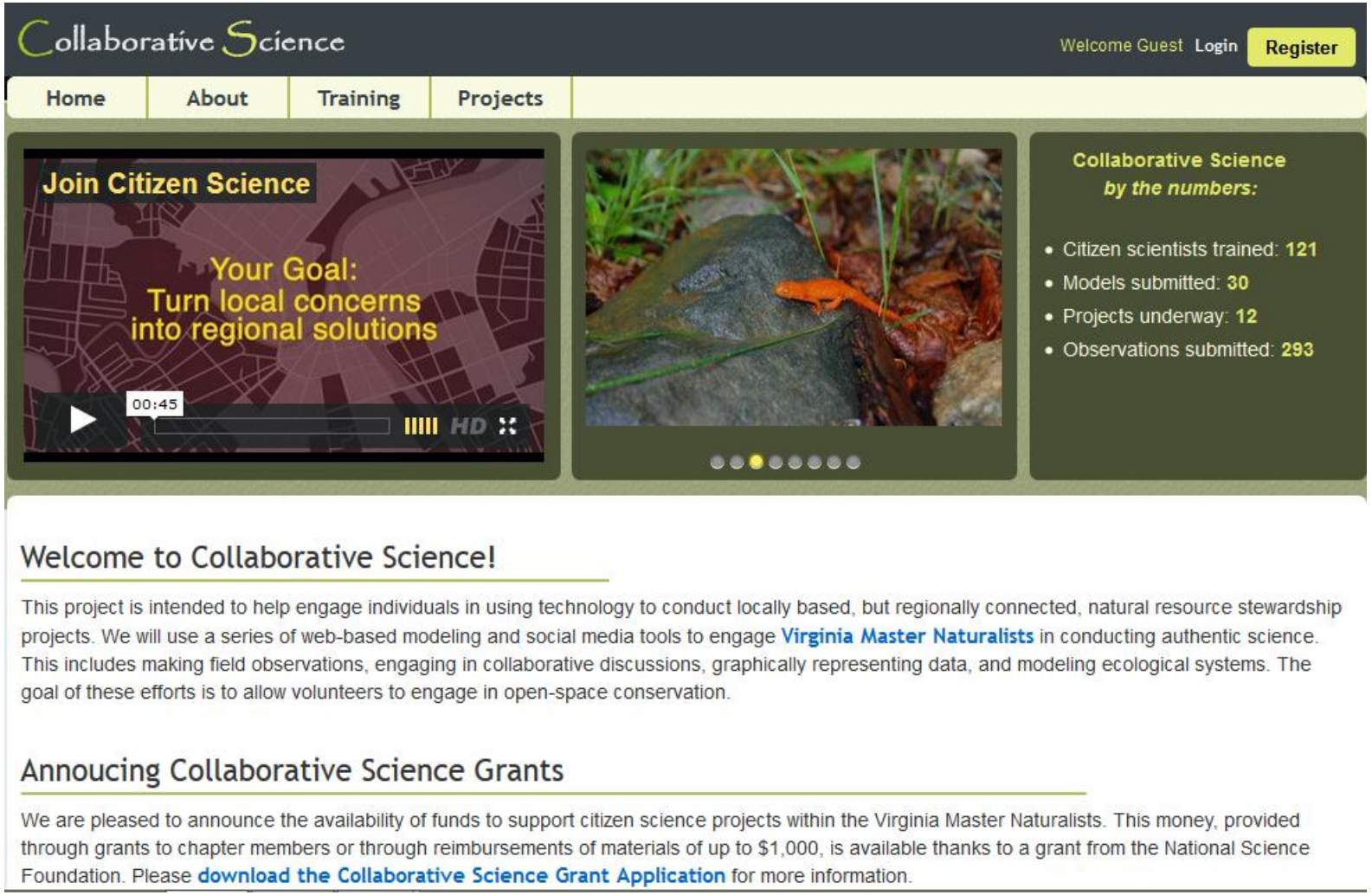




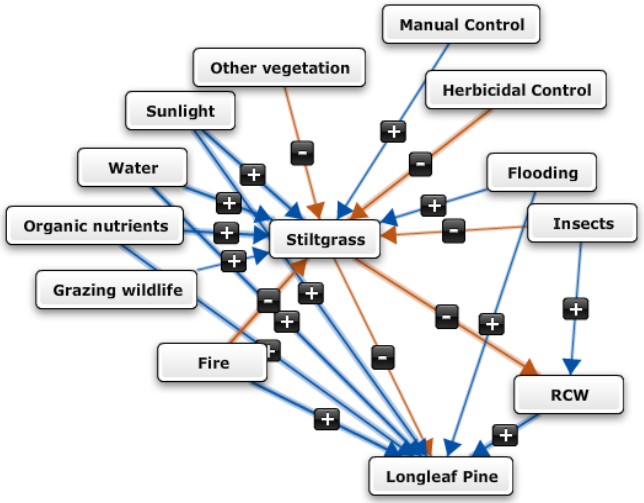
Example?

www.collaborativescience.org

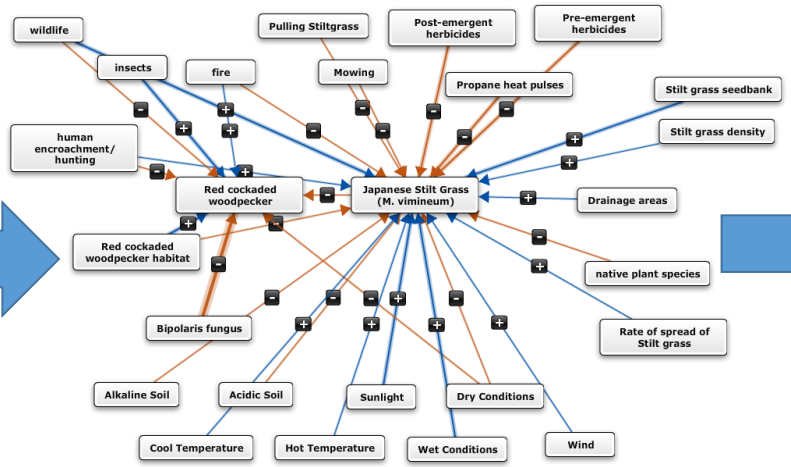


http://collaborativescience.org/cwis438/websites/CyberLearning/Home.php?WebSiteID=16

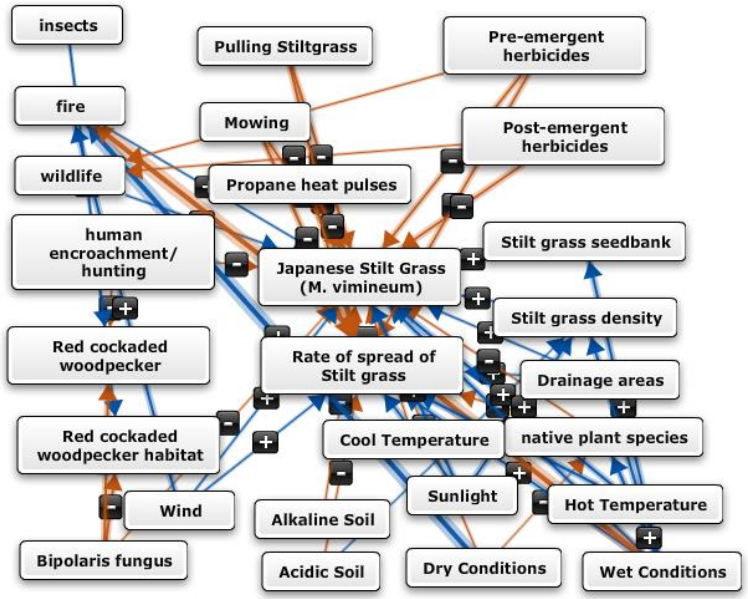
Stilt grass example



Initial Understanding

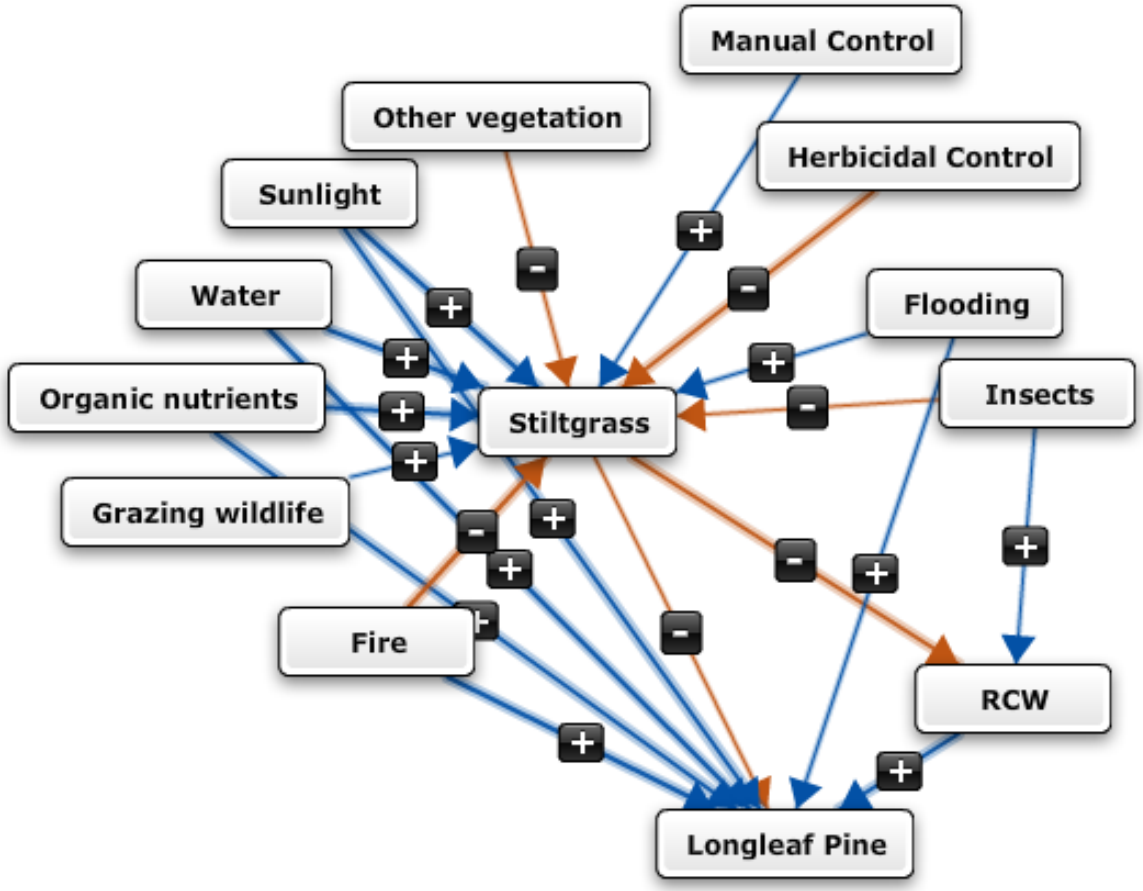


Model built after defining components collaboratively



Final Understanding

Initial Understanding (T1)



Structural Metrics

Number of Concepts: 13
Number of Connections: 19
Density: 1.46
Driving Variables: 10
Receiving Variables: 1
Ordinary: 2
Complexity Score: .10
Hierarchy Score

Most Important Variables Overall

Stiltgrass
Woodpecker

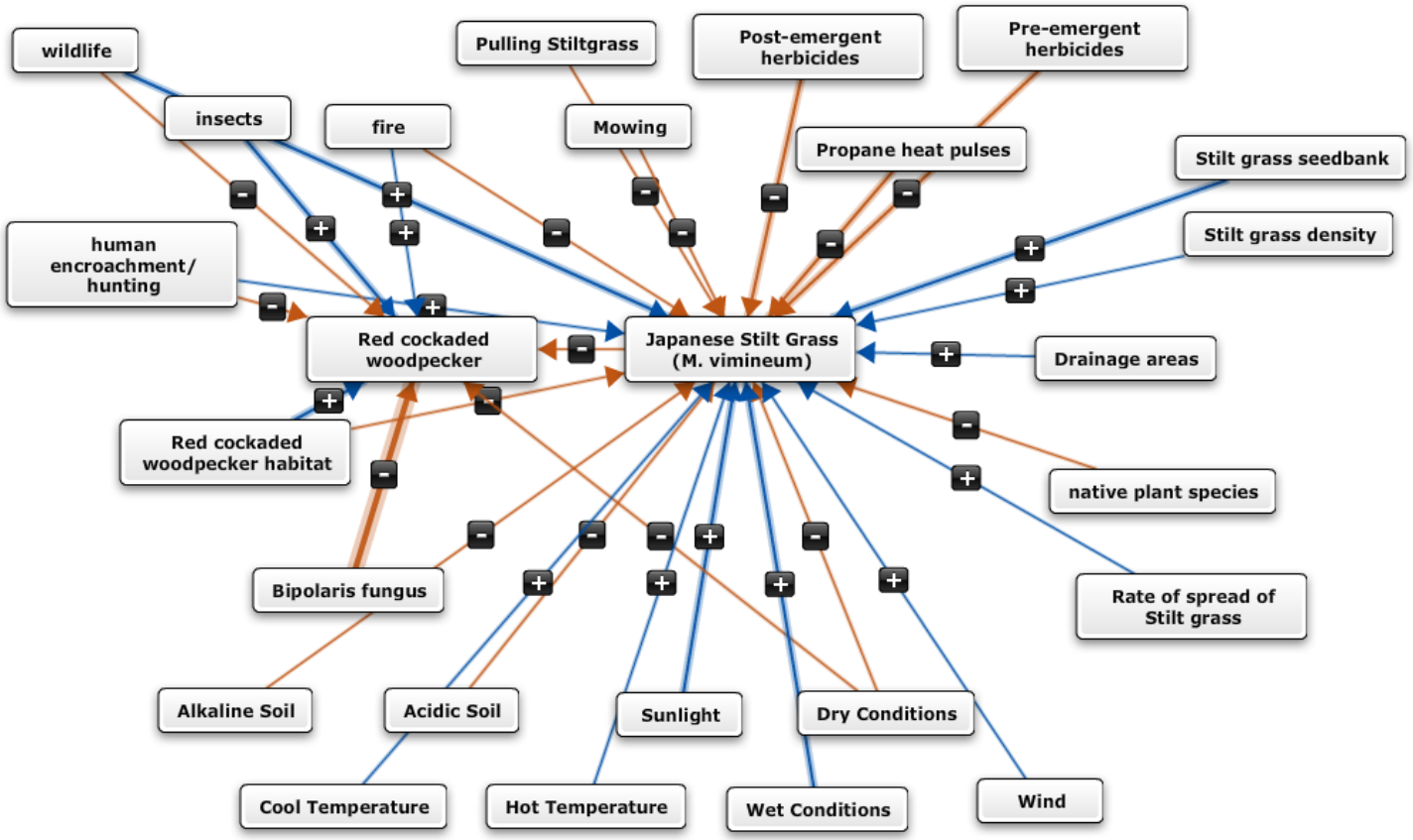
Most Important Drivers

Sunlight
Water
Fire

Most Sensitive

Longleaf Pine

After Collaboration (T2)



Structural Metrics

Number of Concepts: 26
Number of Connections: 30
Density: 1.15
Driving Variables: 24
Receiving Variables: 1
Ordinary: 1
Complexity Score: .041
Hierarchy Score

Most Important Variables Overall

Stiltgrass
Woodpecker

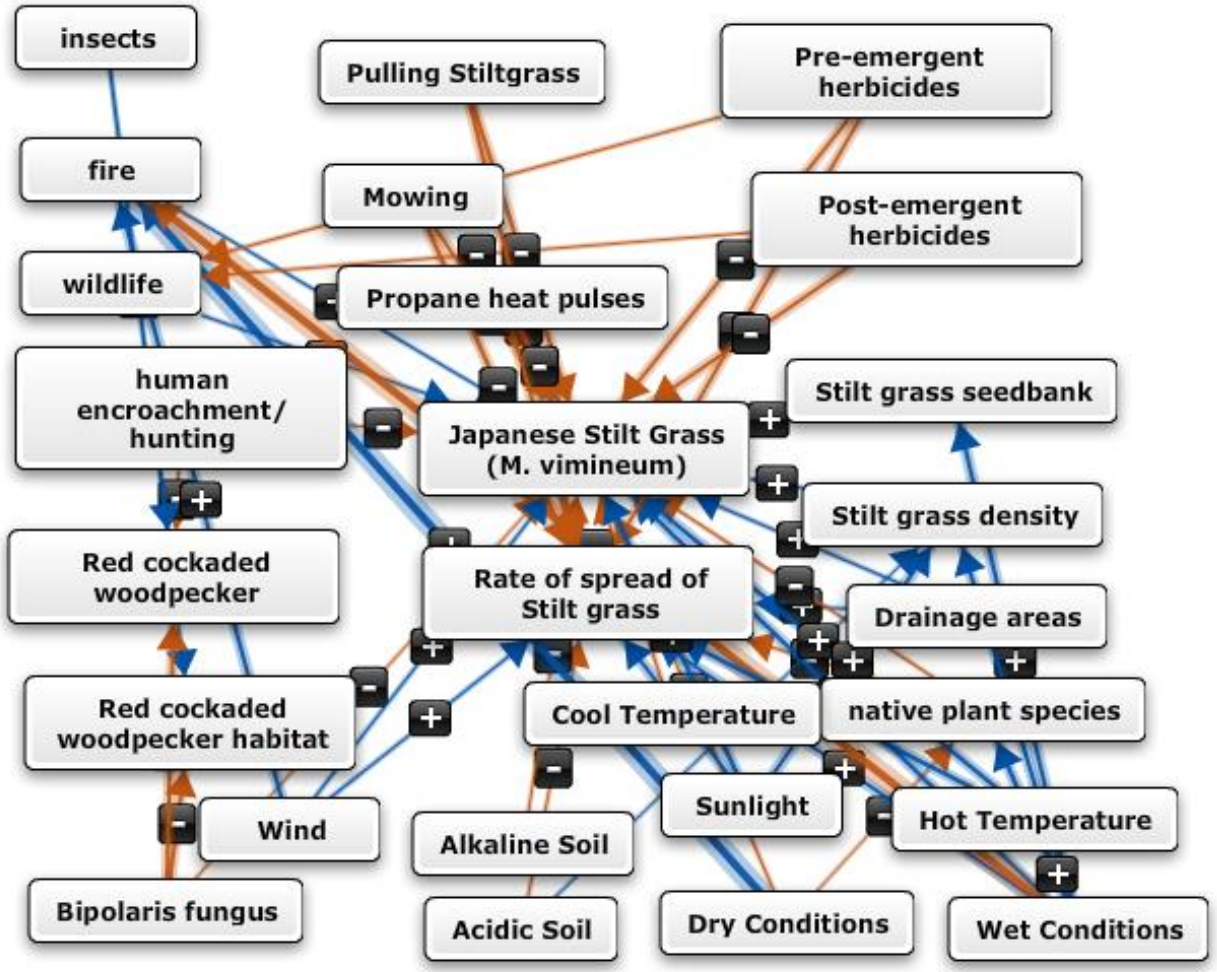
Most Important Drivers

Wet/Dry conditions
Pre-emergent herbicides
Post-emergent herbicides
Fungi

Most Sensitive

Woodpecker

Final Individual Model (T3)



Structural Metrics

Number of Concepts: 26
Number of Connections: 48
Density: 1.84
Driving Variables: 16
Receiving Variables: 4
Ordinary: 6
Complexity Score: .25
Hierarchy Score

Most Important Variables Overall

- Stilgrass
- Rate of Stiltgrass Growth
- Fire
- Wet conditions

Most Important Drivers

- Dry conditions
- Wet Conditions
- Fire

Most Sensitive

- Rate of Stiltrass growth
- Stiltgrass

So what?

- As this person continued through the program:
  - They increased their understanding of the number of factors important to the issue
  - They increased their understanding of the number of relationship between factors (dynamics of the issue)
  - This resulted in overall more dense models as time went on…
  - They increased in their complex understanding of the issue (more feedback loops and less concentration just on ‘driving variables)
  - They shifted their focus from the centrality of the woodpecker and stiltgrass relationship to the influence of wet and dry conditions and fire on the rate of spread of stiltgrass.

One last example…

The overall objective of this course is to:

- *increase students' abilities to analyze complex coupled human-natural coastal systems,*
- *analyze and improve upon proposed sustainable solutions, and*
- *communicate effectively to effect positive change*.

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Choose one (1) of the following four (4) coastal case studies to analyze.

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- *analyze and improve upon proposed sustainable solutions, and*
- *communicate effectively to effect positive change*.

Choose one (1) of the following four (4) coastal case studies to analyze.

I) Introduction (including background, environmental issue(s), changes to the system),

II) Clear statement of the problem,

III) Analysis of the provided solution with three critiques from different perspectives, and

IV) Proposed change(s) to the solution. Any of a number of analytical tools can be used to analyze and communicate the complexity of the system.

Problem of invasives: Mitten Crabs