Fuzzy Cognitive Mapping for Fire Science Applications

An Introduction for Practitioners

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Practitioner Guide, based on Results of JFSP 14-2-01-26: *Policy Scenarios for fire-adapted communities: understanding stakeholder risk-perceptions with FCM*

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Introduction

Fuzzy Cognitive Mapping (FCM) is a technique for representing systems in easy-to-understand visual models, which can also be used for quantitative analyses. The method allows diverse stakeholders, such as community members, scientific experts, and decision-makers to contribute their insights in their own language and to jointly draw conclusions. This can help bridge knowledge, power, and cultural gaps and facilitate collaborative planning efforts for complex socio-ecological problems, such as fire management. Guided by a FCM building and analytical process, groups can make sense of complicated situations and, for example, plan how to best help a community to adapt to fire risk, how to improve inter-agency collaboration, how to balance ecological and economic concerns, or how to address a growing risk of devastating mega-fires. This document provides a practitioner-focused introduction to the method. More details and access to free software is provided at www.mentalmodeling.org.

1. The Basics of Fuzzy Cognitive Mapping

1.1 What Are Fuzzy Cognitive Maps?

FCMs represent causal knowledge (why something happens) as concept-and-arrow diagrams - so called causal maps. In the causal map in Figure 1, concept A causes concept C to increase, while B causes C to decrease. All changes to C happen because (and after) A and B have changed. Concept C causes concept D to change, and therefore concept D is dependent upon concepts A and B. Concepts can be any system element of interest, such as forest resilience, smoke. fire risk. fuel loads. or timber revenue.

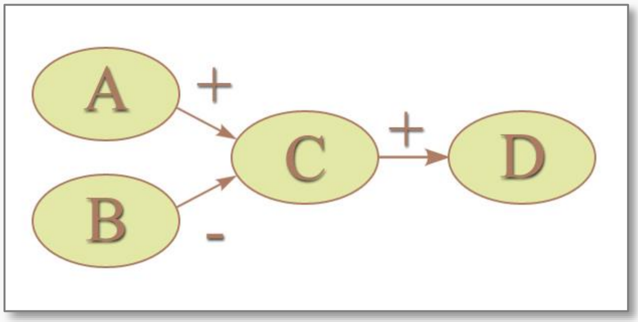

Figure 1: Simple Causal Map

With a bit of guidance, people usually find it quite easy to represent their knowledge as causal maps. They can also read other people's maps, expand on them, and thus jointly build representations of very complex systems. Unfortunately, the resulting maps can be rather difficult to interpret. One particular problem is indeterminacy: In figure 1, it is impossible to say if C will increase (because of A), decrease (because of B), or remain the same (because A and B cancel each other out). FCM addresses this issue by providing a mathematical framework for drawing conclusions about changes of system elements. The first step to this approach is to translate the information in Figure 1 into a matrix format - the so-called adjacency matrix below.

	A	B	C	D
A	0	0	+1	0
B	0	0	-1	0
C	0	0	0	+1
D	0	0	0	0

The first row denotes the causal influences of A on concepts A, B, C, and D. A has no causal influence on itself and none on B, resulting in 0. It causes C to increase, which is denoted as +1. It does not have a direct causal influence on D. Accordingly, the second row shows the causal influences of concepts B on concept A (none = 0), B (none = 0), C (negative = -1), and D (none = 0). The following rows show the same information for C and D. If desired, the strength of a causal relationship can be represented by choosing a weight between -1 (strongly negative) and 1 (strongly positive). Also, it would be possible to represent feedback loops, such as a backward arrow from D to C. In this case the last row of the matrix would read 0 0 1 0.

Conceptually, the concepts in the maps are similar to switches: if they are turned on ("activated") they transmit their activation to other concepts and switch them on as well, provided the impulse is strong enough. Activation thus spreads through the FCM in multiple iterations, as Figure 2 illustrates. When concept A is turned on it is initially the only concept that changes, but iteratively passes this change on to the other concepts it is directly and indirectly connected to, until no more change occurs and a new steady state is reached.

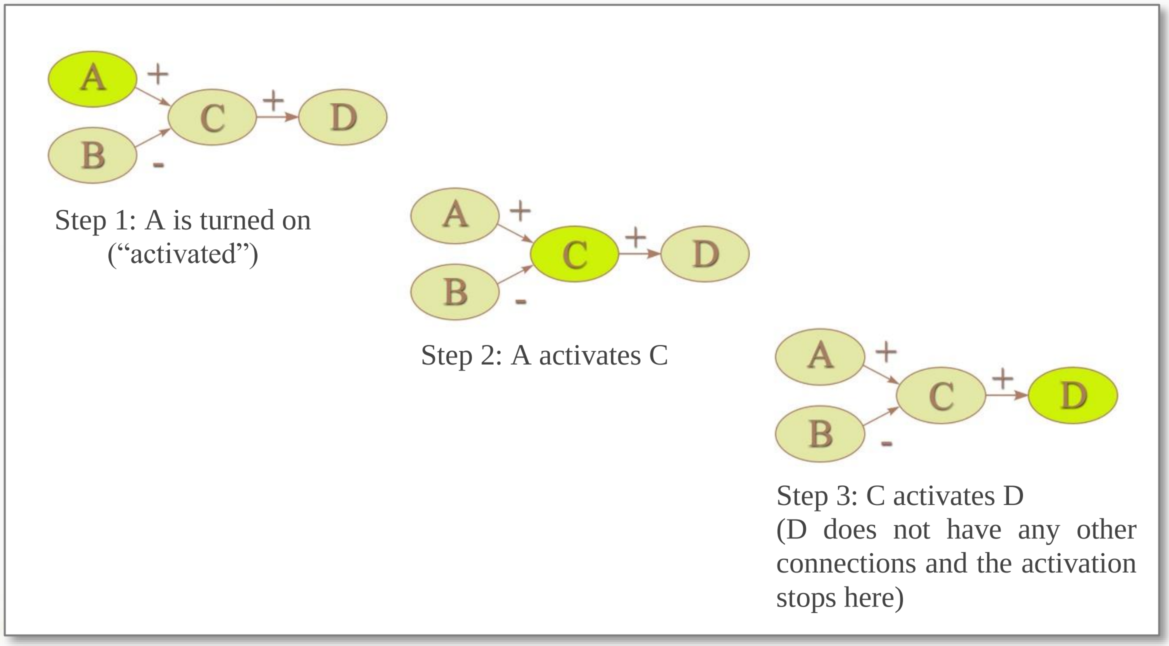

Figure 2. Illustration of "turning on" concepts and how that process impacts other concepts: When A is turned on, it impacts C, which then impacts D.

The change in A could be an external factor, outside the control of the modeling team (e.g., hotter summers, less federal funding, change of public opinion) or an intervention the team may be considering (e.g., improve outreach efforts, allocate more budget to fuel management). By running the model, the team can answer "what if" questions about the system, such as: What are the effects of the external change on concepts of interest? Does a proposed idea have the desired positive effects? Would the proposed idea have unintended consequences for some system elements? Does the idea deliver better or worse results than a competing idea? How does the proposed plan perform under various assumptions?

Mathematically, a model run entails repeated multiplication of the adjacency matrix with a vector that represents the activation level of each concept. When a stable end state is reached, the activation levels of each concept are compared to the concept states the system reaches on its own, without any change. All calculations can be done with the free and easy-to-use software tool Mental Modeler (www.mentalmodeler.org), which does not require a deep understanding of the underlying mathematics. However, if you are interested in more background, please refer to the appendix "Mathematical foundations of FCM".

1.2 Building and Using an FCM Model

Let's assume you want to use an FCM to capture the system concepts and relationships from the following statement:

"People push into formerly uninhabited areas, and more structures and people are exposed to the risks of natural wildland fires. Also, incidents of accidental fire go up because power lines are strung through former wildlands and people operate machinery. Better education on defensible space helps to minimize the harm to property and people, but there will be more fires and our overall risk will increase."

There is no single right way to represent this statement as an FCM; the people creating the model can decide on how to name concepts and show causal connections. Figure 3 shows one possibility where concepts are defined as things that can increase or decrease in quantity or quality.

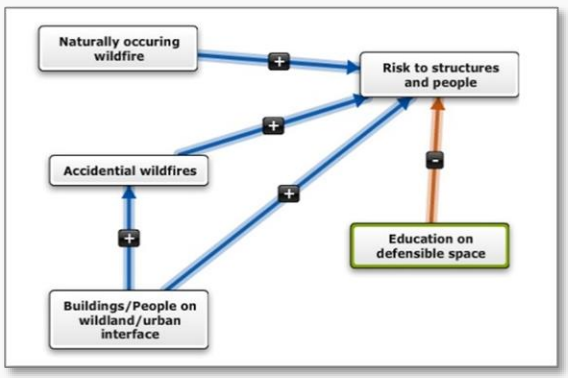

Figure 3. An example FCM in Mental Modeler

In a moderated group setting, the structure and concept names are typically proposed by a facilitator, who runs the session. (S)he should always ask the participants for approval and invite modifications or clarification. In 1:1 interviews, the participants often draw their own causal map, or an interviewer captures answers to interview questions using a drawing or the Mental Modeler software.

Once the model is created, we test if the model behaves as expected or if it needs to be modified before it can be used. Based on the statement above, we would expect accidental fires and overall risks to increase if the number of buildings and people on the wildland-urban interface increase. With the Mental Modeler tool, the results of this test scenario look like this:

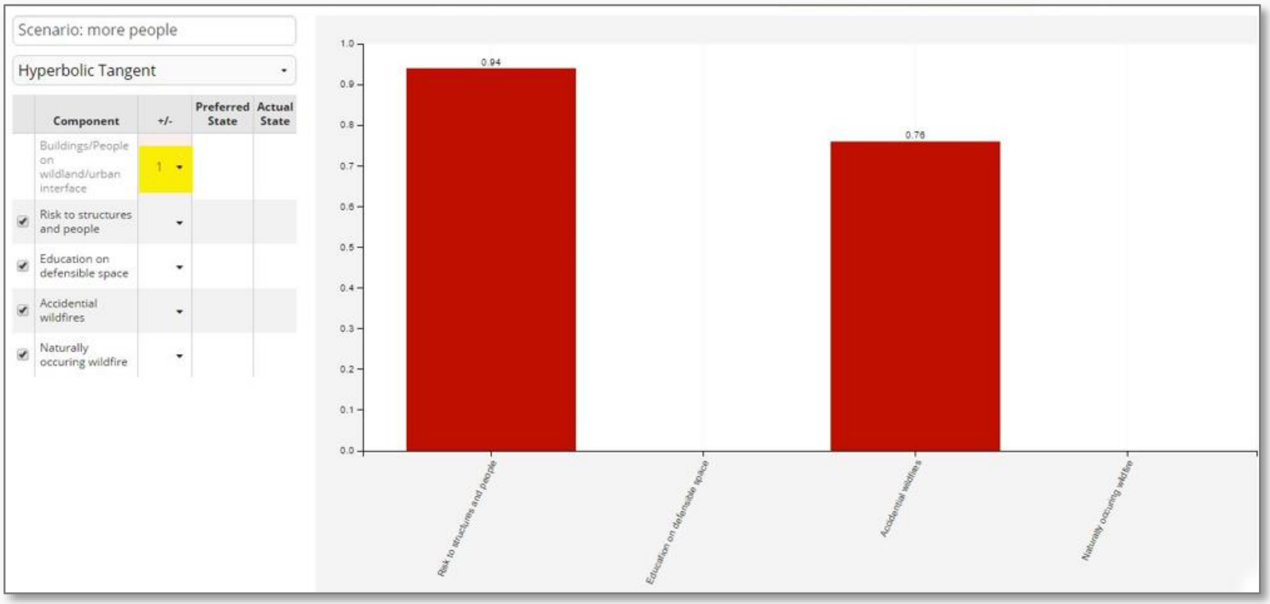

Figure 4. Mental Modeler Scenario Output Based on Activating the Concept "Building/People on Wildland/Urban Interface."

The yellow highlight on the left panel shows the concept that was changed for this scenario ("Building/people on wildland/urban interface" (WUI) was set to 1 to show a high positive increase). The red bars show the change of all other concepts in the system: "Risks to structures and people" and "accidental fires" increase and "education on defensible space" and "natural wildfires" remain unaffected. This means that the model behaves as we would expect it to behave. The size of the bars relative to each other are the important part of the output, and the absolute numbers can be ignored.

Accordingly, we can use the model to test our ideas on how to improve the situation and, for example, determine how much of an impact a better education on defensible space has on changing the expected outcome. Let's assume the education concept is set to the maximum (increased to 1):

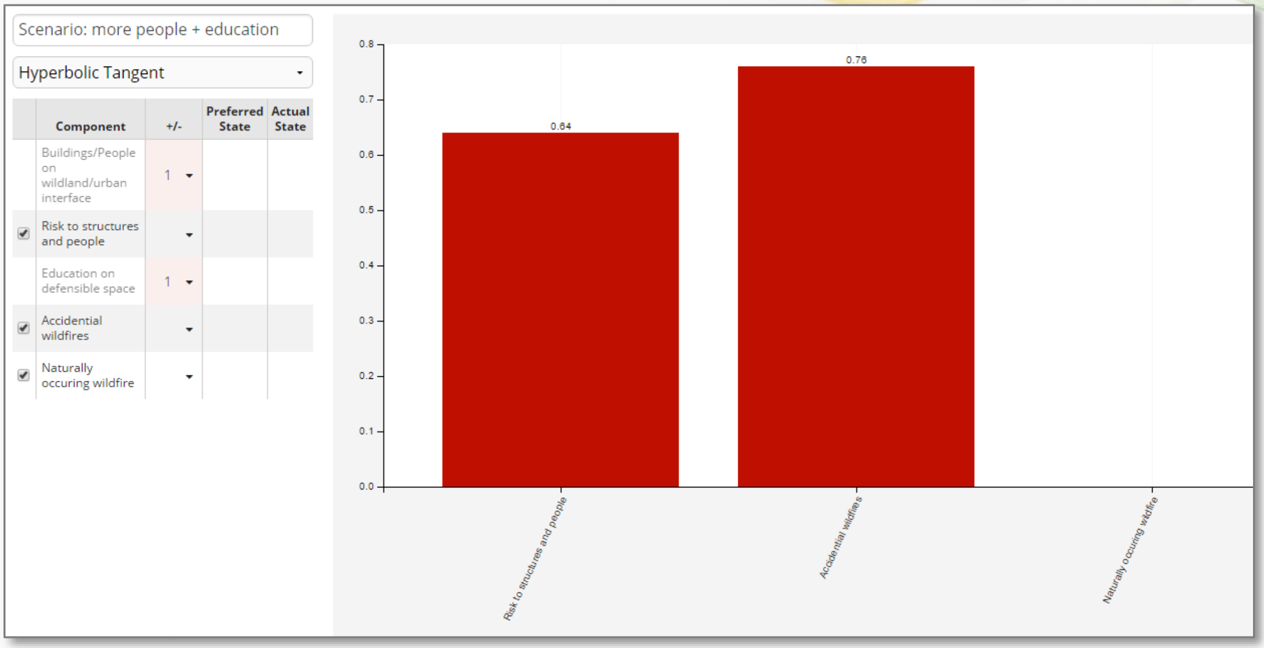

Figure 5. Mental Modeler Scenario Output Based on Activating the Concepts "Building/People on Wildland/Urban Interface" and "Education on Defensible Space"

As is expected, the risk to people and structures still increases in comparison to a situation without people on the WUI, but, thanks to education, the increase is smaller than in the scenario without education. All other concepts remain the same.

Finally, the model could be used to test more complex strategies, such as a combination of reducing the inflow into the WUIs by half and increasing education. The results are shown below:

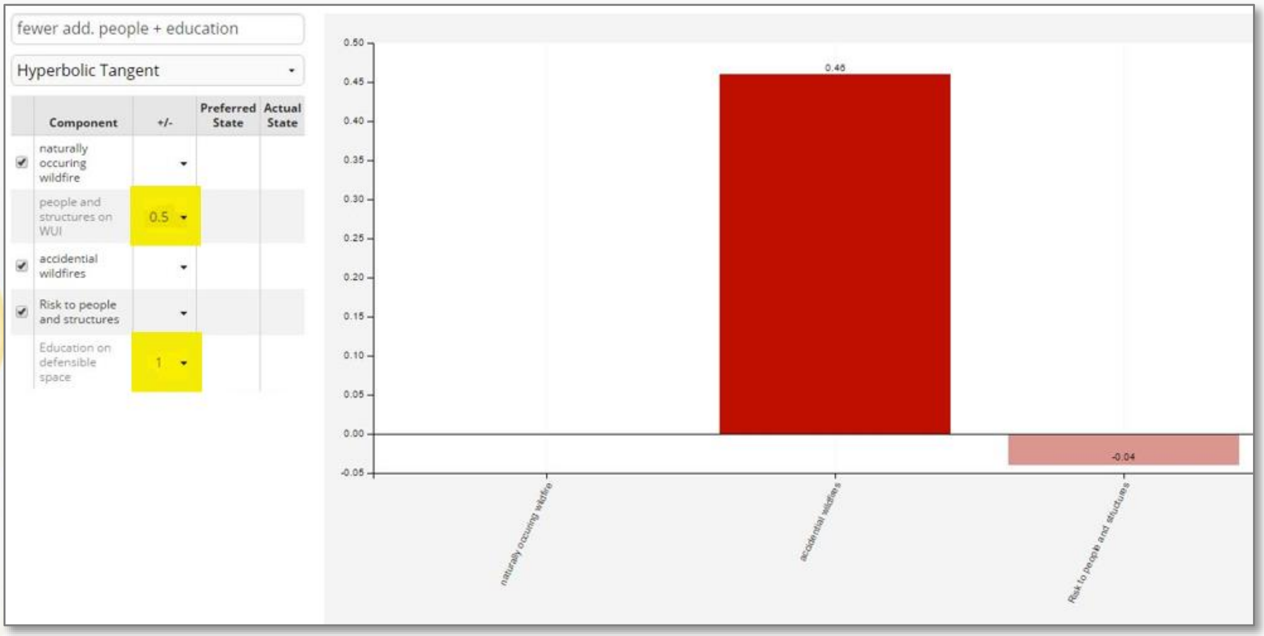

Figure 6. Mental Modeler Scenario Output Based on Activating the Concepts "People and Structures on WUI" and "Education on Defensible Space."

In this scenario, the combined effect of fewer people in harm's way, fewer accidental fires, and better education leads to a small overall reduction in the risk to people and structure.

These model results should not be used as prescription for what to do, but as a tool to facilitate a better understanding of the system under study. In short, the tool is useful for learning, discussion, and planning, and not for probabilistic or deterministic projections. Accordingly, the team should ask itself if the model results make sense as a way to qualitatively validate the model. If yes, participants should explore how robust they are under alternative assumptions: for example, do results change much if there is a weaker causal link between "people/structures" and "accidental fires"? How much do they change when a different squashing function is selected? How strong is the impact of education if other elements are added to the model? If model results are unexpected, the team should look for missing concepts, feedback loops, and indirect effects that they may have missed and that could explain the unexpected behavior. Moreover, the team needs to have a discussion about goals and about what is feasible. In above example, does the team need to decrease risks to people and structures? Or does it aim to curb the increase? Is it feasible to reduce the inflow of people into wildlands? Is it desirable, given other community objectives, such as economic growth? The ultimate purpose of the models is to help stakeholders and decision-makers make sense of a complex situation and

2. Creating Your Own FCM Project

2.1 What's the Purpose?

FCM can serve collaborative planning efforts in two distinct ways: first, as illustrated above, it can be used to create simulation models of a complex problem for the purpose of prediction, sensemaking, and decision support. If this is the main purpose of the FCM model, participants are selected based on their expertise, not necessarily their position or investment in the issue. Great care should be given to precisely reflecting expert knowledge in the FCM model. Accordingly, concepts should be clearly defined (often upfront, before the actual modeling session) and consistently used throughout the study. Wherever possible, model results are compared against available data.

A second purpose of FCM modeling, which is the background of our case study in document XY, is to document and communicate how different stakeholders think about a complex issue, even if their views are limited or may contradict scientific knowledge. It should be noted, however, that often times FCM is used to enhance or contextualize scientific knowledge. These insights are helpful for understanding conflict and opposition to proposed actions, highlighting needs for improved communication, identifying potential for collaboration between stakeholders, and for building capacity to take collective action. If this is the main purpose of an FCM study, participants are selected based on their stake in the planning process and results, their ability to speak for and organize other community members, and their specific local knowledge (which may be limited to only certain parts of the overall system). To make sure that they feel included and can participate on equal footing, modeling sessions typically use non-scientific language that captures how the participants express their thoughts.

Modeling is focused on creating an FCM that is useful as a communication tool, which may require detailed concepts and connections, even if they do not contribute much to the mathematical model. (For example, in one of our workshops, the participants differentiated between smoke from a local wildfire vs. smoke from remote fires and kept this distinction, even though they attributed no different effects to these two types of smoke; the proximity of the fire is important to the public perception of the fire). Models like this should not be expected to correctly represent the system's real-world behavior, but the stakeholder's perspectives. These models often require some additional cleaning/standardization steps to be useful as a simulation tool and may only have limited predictive powers.

2.2 Preparing the Modeling Workshop

Before you run your modeling workshop, make sure to clearly define the problem you are trying to solve with mental modeling. This helps structure the approach you'll take in your modeling process and prevent workshops during which stakeholders attempt to capture everything they know about the system. A good starting point is to define a few concepts (or goals) that you want the stakeholders to include in their models. Of course, your goals may shift throughout the process, but it's important to have your specific problem defined before you begin the process.

Next, define the system boundaries. Determining what not to include will help you think more specifically about the structure of the model itself and will help limit discussions to relevant concepts. Check how prepared you are: can you explain to the group what aspects should be out of scope for the study? Do you have a list of sample questions you can use to motivate responses if necessary?

Determine who to invite for your particular project. Recruit people who have a diversity of expert knowledge. This can entail formal education or local knowledge or experiential knowledge. Include people who can help make workshop recommendations a reality, so that they can buy into the process. Invite people who are particularly affected by the workshop topic and need to have their voices heard. Also, think about whether you want homogeneous or heterogeneous groups of stakeholders: sometimes it is vital that all stakeholder groups hear from each other. Sometimes it may be better to first meet and create FCM with stakeholders from each group before you bring all of them together.

2.3. Running the Modeling Workshop

Begin each workshop with introductions and a brief educational activity that explains mental models, fuzzy cognitive maps, and the purpose and ground rules of your workshop. Pick a simple, everyday example to illustrate how you will collect the information (e.g., Mental Modeler software, index cards or sticky notes, structured interview questions). When using Mental Modeler, which we recommend based on its functionality, project onto a large screen so that everyone can see the model develop in real time. Before jumping into the questions, you want to address make sure the group understand to build a model. Let them briefly practice with an unrelated example. This ensures that they understand how to build a model.

Depending on your group and your questions, you may begin with a list of clearly defined concepts that the model will include, or you might want to begin with just a few concepts. Be sure to include any concepts that are necessary for your research question (i.e., if you are asking about a specific policy option, make sure to include that option as a concept). For example, in one case study, we wanted to understand how stakeholders think about different approaches to using fire as a forest management tool. We began with the starter concepts of "Managed natural ignition," "controlled burning," and "smoke." This ensured that the relevant policies were discussed, and that the group has an idea of how to connect policies to impacts. Whether you provide all the concepts, or just a few, the first step is to ask about the relationship between those concepts. This will elicit further information about what concepts need to be added and how they fit together.

Make sure that concepts are well enough defined that the people in workshop understand the meaning of their FCM. However, steer people away from overly detailed concept definitions unless you get a sense that they are important and useful to the entire group. To stop fruitless discussions, it can help to split the debated concept into two similar concepts with slightly different meanings, rather than trying to resolve the issue.

Ask clarifying and confirmatory questions throughout the workshop, such as "Did I get this right? Would you agree if I rephrase this as ….? Is this what you mean?" Make sure to ask specifically about the direction of relationships and about feedback loops. Remind participants that concepts need to be able to increase or decrease. You may want to have participants assign specific weights during the model-building workshop, particularly if you are working only with experts, or you may find it easier to simply ask if a relationship is strong or weak, and assign general weights based on the response. The exact weight of a relationship is less important than the general strength of the relationship. If participants disagree about a concept or relationship between concepts, have a conversation about that disagreement and add new concepts or relationships as needed. If agreement cannot be found, make note of that. In a group setting, there will always be some disagreement, but we have found that through discussion, and through adding or taking away concepts, and changing relationships, the group is usually able to come to at least some consensus, and be able to move forward.

Once the model is complete, run some scenarios with the group. Ask them if the scenario outcomes are what they expected to happen based on their understanding of how the system functions. If there are discrepancies between the scenario output and their expectations, return to the model and look at the concepts and connections to see where the model is different that the stakeholders' beliefs. Once the stakeholders have verified that the scenario output corresponds with their expectations, the model is complete.

At this point, you can analyze the model in whatever ways make sense for your questions. If you revise the model in order to analyze it, (i.e., standardizing concepts in order to compare or aggregate, creating submodels in order to look at a specific part of the entire system, or aggregating multiple models), make sure you share these revisions with the stakeholders if you can. This provides transparency in the process for future decision-making, and also ensures that the stakeholders stay involved and confident that their perspectives are being included.

2.4. Analyzing FCM Models

The completed models can be analyzed with regard to the model structure (i.e., how concepts are connected), model function (i.e., how the modeled system behaves), and model content (i.e., what topics are covered).

2.4.1 Structural Metrics

Figure 7 shows structural metrics for an FCM on the impacts of managed natural ignition and prescribed burns:

Total Components	18
Total Connections	49
Density	0.160130719
Connections per Component	2.7222222222
Number of Driver Components	1
Number of Receiver Components	5
Number of Ordinary Components	12
Complexity Score	5

Component	Indegree	Outdegree	Centrality
Public Acceptance of Actions	4.66	1.97	6.63
Public Health	0.61	0	0.61
Personal and Respectful Communication	0.88	2.3	3.1799999999999997
Trust	1.4500000000000002	2.02	3.47
Outreach and Education	0.72	4.8100000000000005	5.53
Economic Health	0.97	0	0.97
Smoke	2.5	1.88	4.38
Action: Controlled or Prescribed Burning	2.58	2.79	5.37
Action: Managed Natural Ignition	2.14	2.8600000000000003	5
Aesthetics	1	0	1
Innovative Alternative Approaches to Fuel and Smoke Managmement	2.41	1.67	4.08
Scientific and Technincal Information	0	2.38	2.38
Forest Health	1.48	0	1.48
Climate Change	1.3900000000000001	0	1.3900000000000001

Figure 7: Selected Structural Metrics (Screenshot from Mental Modeler Software)

The number of concepts (components) shows how many different system elements were identified. The number of connections between components indicate the degree of connectedness between components. The centrality scores of individual variables represent the degree of relative importance of a system component to system operation. In- and Out-degree show how many arrows are pointing at/from a concept. Concepts with high indegree are influenced strongly by other concepts and are so-called receiving variables. Concepts with high outdegree are influencers, or driving variables. Concepts with an equal number of in and out arrows are ordinary variables. The overall number of transmitting, receiving, or ordinary variables and the complexity scores indicate whether the system is viewed as largely comprised of driving components or whether the outcomes of driving forces are considered (i.e., that some components are only influenced). Density scores are associated with the perceived number of options that are possible to influence change within a system, as the relative number of connections per concept indicate the potential to alter how a given system functions.

2.4.2 Functional Analysis

Functional (also, dynamic or scenario) analysis (see 1.2 for examples of running scenarios), allows an understanding of how the stakeholders understand the impacts of change. Concepts are turned on or off to show how the system would react under a range of policy, social, or environmental changes. Functional analysis lets you compare the predicted outcomes of a range of policy options to make better and more informed decisions. For example, the impacts of different wildfire mitigation strategies, such as prescribed burns or managed natural ignition or suppression, can be compared by running scenarios with each of those concepts turned on.

2.4.3 Content Analysis

Content Analysis encompasses a variety of methods that look at the meaning of the concepts that are included in a model, how frequently they are mentioned, and by whom. The analysis can be supported with content analysis tools, such as atlas.ti or NVivo. Figure 8 shows a so-called word cloud of concepts that were mentioned in five stakeholder workshops on using fire for forest management. The size of the letters indicates the frequency of the concept in all stakeholder workshops, indicating concepts of shared interest.

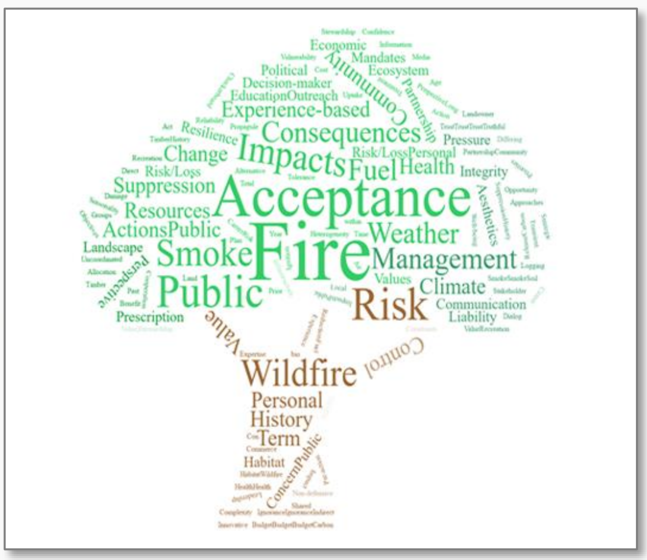

Figure 8: Word Cloud - a Simple Example of Content Analysis

Content analysis techniques can also be used to categorize concepts that belong to the same topic, such as all risk-related concepts, all concepts about government regulation, or all concepts that contain an idea for a solution.

2.5 Optional: Comparing and Combining FCM Models

Occasionally, it makes sense to engage with stakeholder groups separately and create group-specific FCM models that reflect the distinct knowledge and perspectives of each group. In these cases, it is often desirable to compare FCM models against each other. In other cases, researchers aim to synthesize the knowledge from different sources into a combined model that represents the cumulative insights from different groups. Both represent special cases of FCM analysis:

2.5.1 Comparing FCM models

The cross-comparison of group-specific stakeholder models occurs with the same analysis techniques that were already described above: structural, functional, and content metrics are used to identify similarities and differences between groups.

Structural metrics can look at things like complexity and density of the model, which concepts are important drivers of the system ("transmitters"), which concepts are receiver variables, and which concepts are most central to the system. Looking at these types of metrics across models from different stakeholders or stakeholder groups shows how diverse perceptions

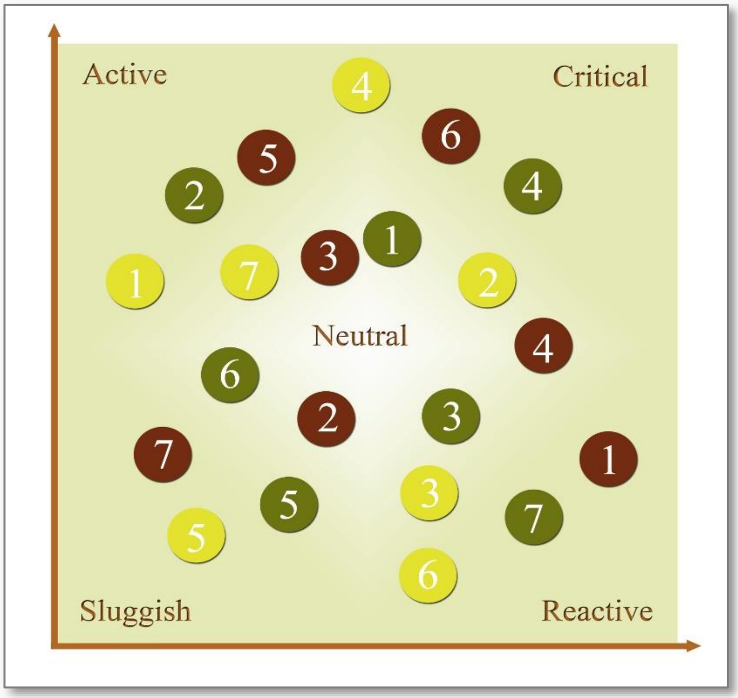

Figure 9: Nature of Concepts in a System Grid

Figure 9 shows an example of one possible structural comparison: concepts from three different stakeholder maps are mapped into a matrix (the so-called system grid) to show if the stakeholders consider them active (also: transmitter driver), reactive (also: receiver, passive) or ordinary variables with both, in – and out arrows, which can be further differentiated as sluggish, neutral, and critical. Analyses like this can, for example, show that one group may perceive community outreach to be a strong driver of fire management practices, while another group may simply see it as a receiver variable. The first group likely wants to increase outreach to leverage the system, while the other group sees little reason to do so, even though both groups consider community outreach to be a part of the system under study. Comparing these two different perspectives shows how difficult it might be to arrive at any consensus about how to best mitigate wildfire.

Comparing stakeholder FCM through functional analysis occurs by running the same scenario in different, stakeholder-specific FCMs. This is used to show how the stakeholder groups think about different policy options or system changes.

Figures 10 and 11 show scenario results as a result of a particular fire management practice (here, increasing managed natural ignition for resource benefits). The two different stakeholder groups made different predictions. In doing so, they focused on different aspects, with the first group focusing on a broader variety of impacts, including social, health, and environmental impacts, while the second group focused only on environmental impacts.

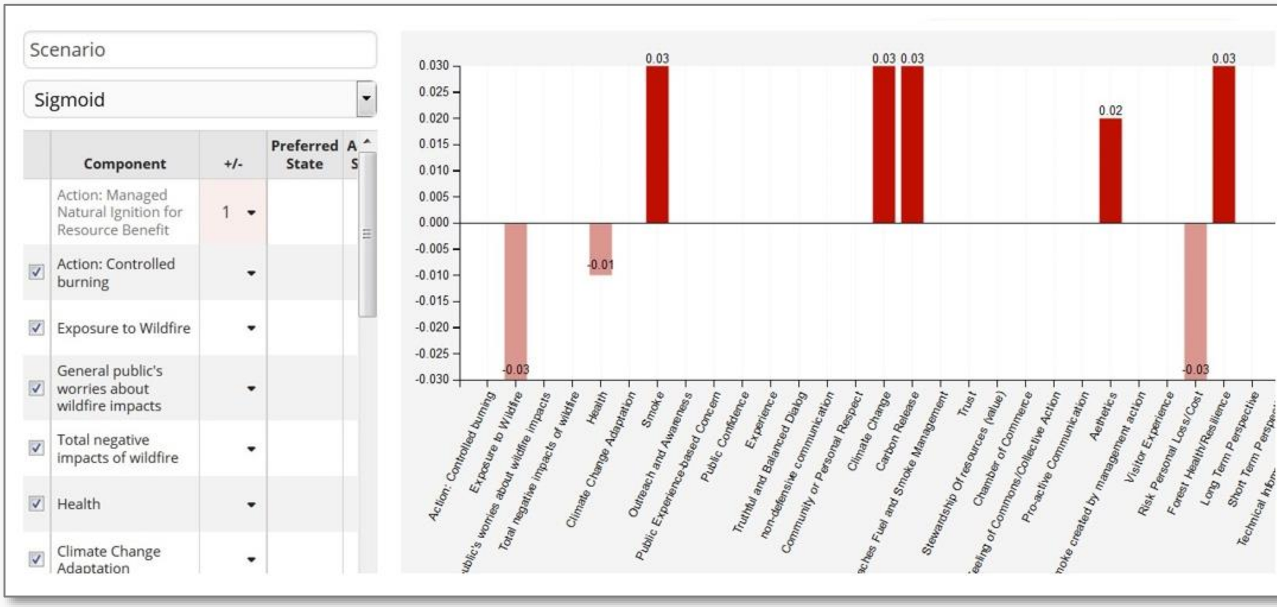

Figure 10. Stakeholder Group 1 Scenario Output Based on Activating "Managed Natural Ignition"

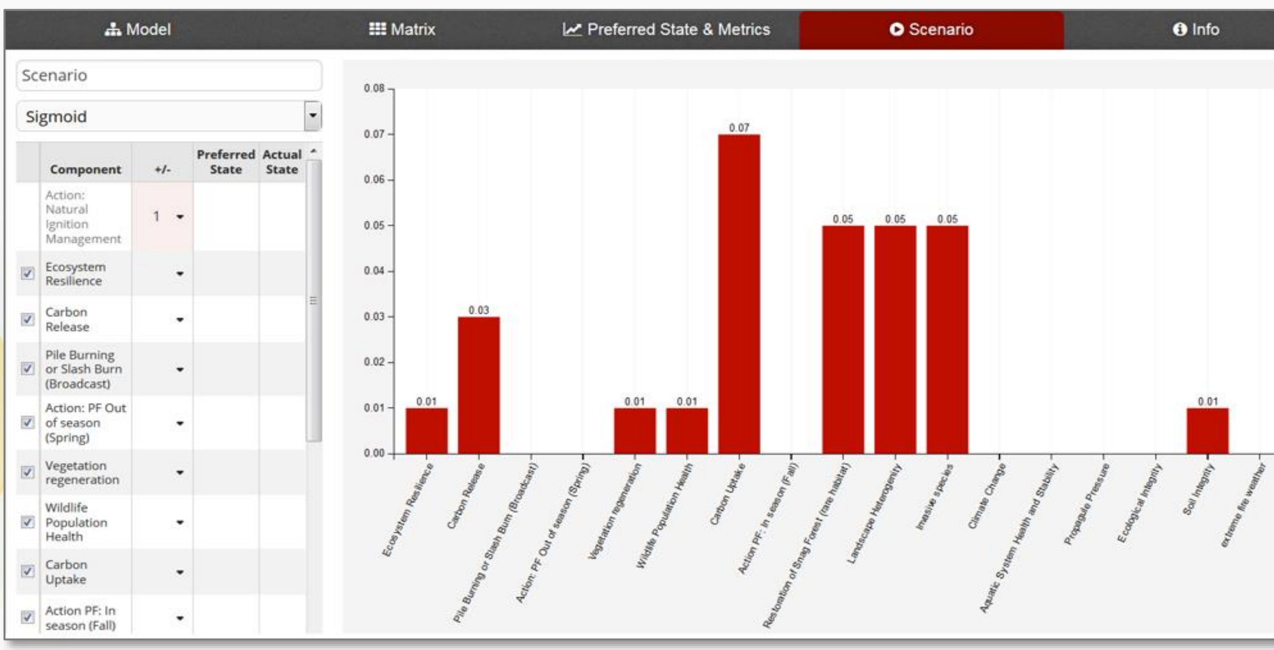

Figure 11. Stakeholder Group 2 Scenario Output Based on Activating "Managed Natural Ignition"

Some of the predicted impacts from increasing managed natural ignition are similar for both groups, such as carbon release and forest health. However, the first group also included impacts to public health, and focused on personal risk and the aesthetics of their community and surroundings. Comparing the outcomes of the same scenario in different models highlights where there is consensus and where there are differences, which is helpful for future communications and discussions about policy implementation and decision-making.

Content comparison across stakeholder FCM occurs by determining if (and possibly also how frequently) concepts or concept categories are included in the stakeholder-specific FCM models. This also shows how much overlap exists between the different models. Figure 12 shows a Venn diagram that shows the number of unique and overlapping concepts for four different stakeholder groups, each of which is represented by a circle. The four concepts in the middle are shared across all groups.

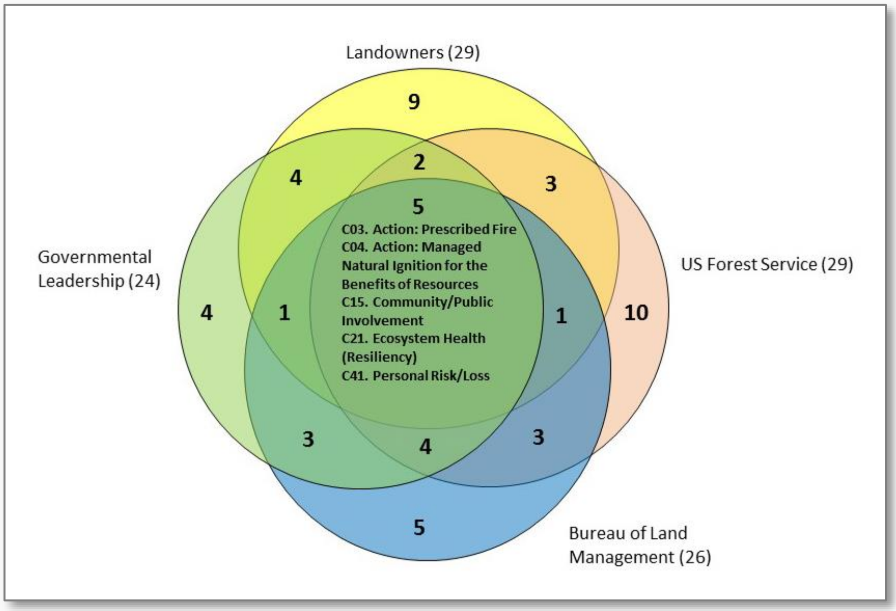

Figure 12: Venn Diagram, Showing Unique and Shared Concepts Across Stakeholder Groups

The comparison of stakeholder FCMs can support fire management by identifying areas of agreement that can be leveraged to help stakeholders come together, as well as areas of disagreement that can be barriers to collective action. Moreover, it shows which stakeholders "think alike" and are therefore likely to join forces, versus stakeholders who may experience conflict.

2.5.2 Combining FCM Models

In some instances, you may want to pool the insights from the stakeholder-group specific FCMs and integrate them into a single FCM model. This is possible when the stakeholders have used standardized concepts (e.g., concept C1 is "forest resilience" in each of the stakeholder models) or all concepts have been standardized by the researchers after the workshops have concluded. In this case, a simple mathematical integration is possible, as Figure 13 illustrates.

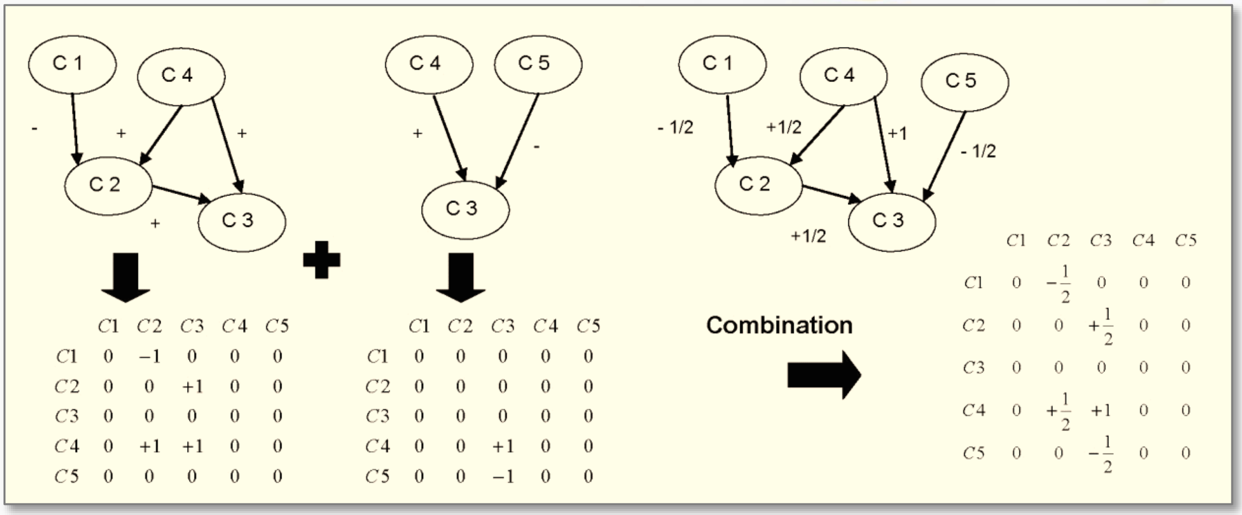

Figure 13: Mathematical Integration of Two FCMs

This approach requires that the adjacency matrices for each model have the same size. This can be achieved by adding rows and columns that are all zero. The resulting map can be used as the starting point for discussions in an all-stakeholder meeting.

2.6 Presenting Results

How to present results is entirely dependent upon the purpose of the FCM building defined at the start of the project, and who the involved stakeholders are. It is often useful to hold a final meeting in which all stakeholders are invited, both those involved with the modeling process itself and those who are invested in the issue but were not involved with the modeling. Alternatively, you may find it more useful to present results to individual stakeholder groups, particularly if there are high levels of conflict between groups. If the models are used to inform decision-makers, then additional meetings with the stakeholder groups may not be necessary, particularly if they already verified the model and agreed with any revisions. However, the results are presented, it is important to be transparent about the purpose of the FCM, and the process you took. It is often useful to show the models and then run scenarios in real time, so that your audience can see the dynamic simulation.

In some cases, the best way to present results might be through a hands-on, interactive workshop, in which participants manipulate the models and run their own scenarios. These can be structured in various ways. For example, we allowed people to play with models created by other stakeholder groups, which allowed them insight into different perspectives. This led to a broader understanding of the complexity of the issue, and the difficulties faced in mitigating wildfires. In particular, playing with other stakeholders' models highlighted the barriers to addressing wildfire, particularly those based on laws and regulations.

3. Conclusions

FCMs, and the Mental Modeler tool, can be powerful tools for exploring complex socio-environmental problems, such as wildfire. The method allows diverse stakeholders, such as community members, scientific experts, and decision-makers to contribute their insights in their own language and to jointly draw conclusions. However, to fully utilize the full capabilities of Mental Modeler and fuzzy cognitive mapping, it is important to make sure your questions and processes are well planned out. FCM is a dynamic tool, and therefore you will surely have to adapt to stakeholder needs, but if you have prepared these adaptations will lead to more robust and useful models.

Mental Modeler lets you explore the potential outcomes of diverse decisions based on stakeholder knowledge and beliefs. When dealing with complex issues, it is often useful to be aware of the diversity of perspectives, particularly when dealing with community and environmental issues. There probably won't be one solution that works for everybody and everything, but by collecting as much information as possible, you can work collaboratively to make more informed decisions.

Appendix: Mathematical Background of FCM

The following matrix is an adjacency matrix for an FCM with 5 concepts. Other than in section 1.1. the edge weights are not simply + or - but weighed between -1 and 1. The weights can be determined by stakeholders, who can give quantitative weights or use verbal scales (very strong, strong, medium, weak, very weak), that are subsequently translated into quantitative values.

1	0	0,7	0	0
0	1	-1	0	1
0	0	0.5	0	0
0.3	0	0	0	0
0	1	0	0	0

To calculate the impact of only activating concept A, we need to create a state vector that shows the first concept activated and all other concepts set to 0. It is: (1 0 0 0 0). This state vector is multiplied with the adjacency matrix, resulting in a new vector: (1 0 0.7 0 0)

A so-called squashing function sets the vector's values into the range of (-1, 1) or (0,1). In our case, we use a sigmoid squashing function[1]:

$$f(x) = \frac{1}{1 + e^{-\lambda x}}$$

[1] Squashing functions are non-continuous functions that are commonly used in artificial neural networks. FCM researchers commonly use binary functions, trivalent functions, sigmoid functions (see above) and hyperbolic tangent functions.

The resulting vector after this operation is:

After iteration 1 and squashing function: 0.73 0.5 0.67 0.5 0.5

It is again multiplied with the adjacency matrix and subjected to the squashing function. The process is repeated until the resulting state vector is identical to the prior vector. In this example, this occurs after 6 iterations:

2. Activation	0.86	1	0.35	0	0.5
2. Normalization (Squashing function)	0.7	0.73	0.59	0.5	0.62
3. Activation	0.83	1.35	0.05	0	0.73
3. Normalization (Squashing function)	0.7	0.79	0.51	0.5	0.68
4. Activation	0.82	1.47	-0.1	0	0.79
4. Normalization (Squashing function)	0.69	0.81	0.49	0.5	0.69
5. Activation	0.82	1.5	-0.1	0	0.81
5. Normalization (Squashing function)	0.69	0.82	0.48	0.5	0.69
6. Activation	0.82	1.51	-0.1	0	0.82
6. Normalization (Squashing function)	0.69	0.82	0.48	0.5	0.69

If the activated concept is not a one-time event but a continuing change that lasts through all iterations it can be “clamped,” which means it is reset to its initial activation level after each iteration. Mental Modeler clamps concepts at its activation level. The software’s scenario function compares the last iteration, at which the system reaches a stable state, against the stable state that results from activating (but not clamping) all concepts to 1.

4. References and Further Reading

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