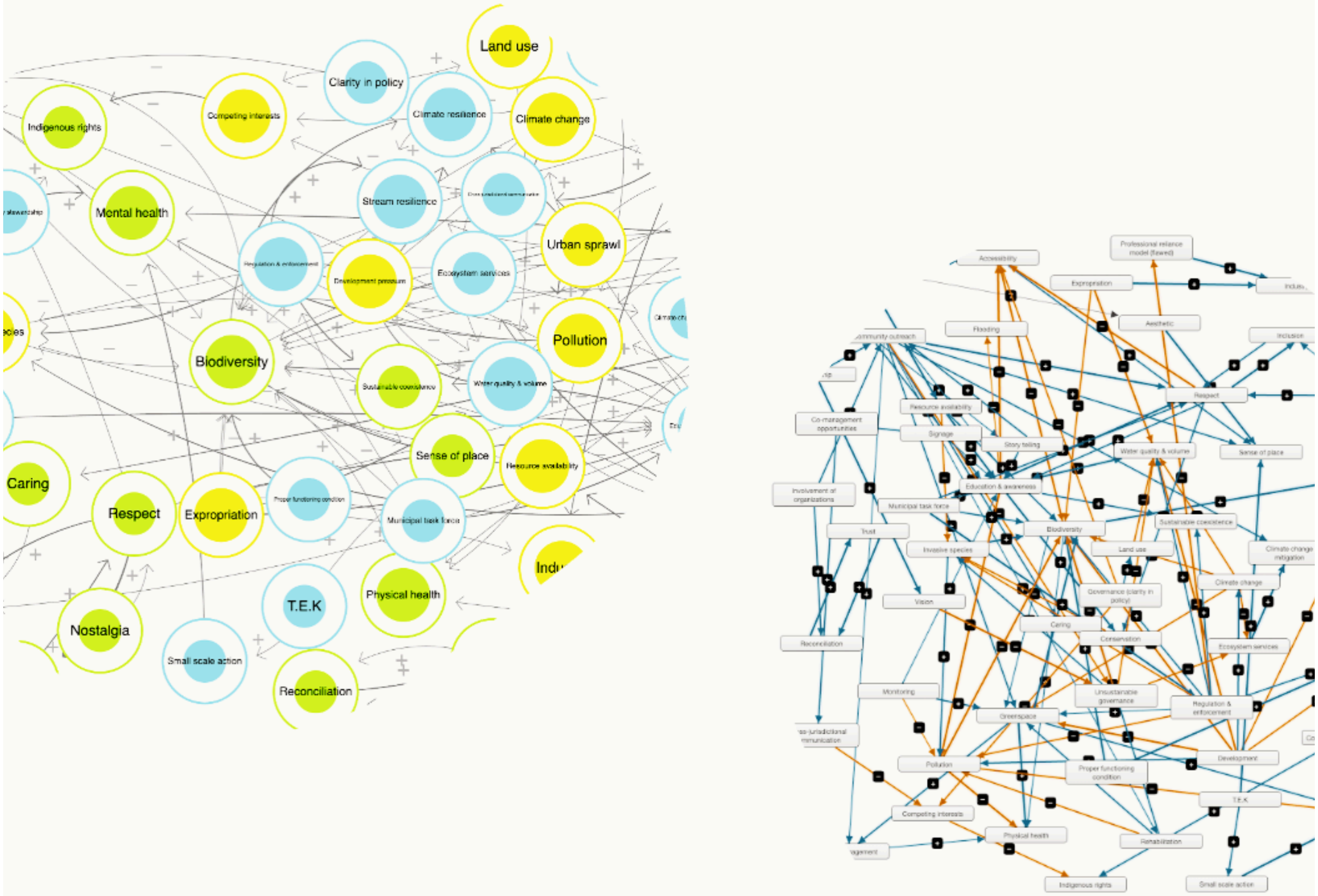


# A Comparative Study of Systems Mapping and Scenario Analysis Tools

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## Introduction

Community participation is valuable for producing and disseminating practical knowledge on local issues that affect a community. Such participation can be facilitated through participatory research. Participatory research involves individuals who represent the interests of the community and/or issue being studied but may lack formal research training [1]. Participatory research engages participants in ways that allow them to effectively express their thoughts about the subject of the study. Such engagement ensures that the knowledge generated from the research reflects the needs and perspectives of the relevant individuals and community.

Several methods and techniques are used in participatory research, including fuzzy cognitive mapping. Fuzzy cognitive mapping involves modeling the systems relationships and dynamics around an issue or phenomena using research participants' (i.e., stakeholders') understanding of a complex problem or topic. A fuzzy cognitive map consists of nodes (components or elements) that are linked by edges (relationships or connections). The edges have associated ratings, which represent the strengths of the relationships or connections between the nodes.

The process of building a 'system map' via fuzzy cognitive mapping involves several steps. First, the key components or elements relevant to an issue, topic, or phenomena are identified. These components then become the nodes in the systems map. Second, the relationships between the nodes are identified by drawing edges that represent the connections or interactions between the systems components. Third, ratings are assigned to the connections, which quantify the strengths and natures (i.e., positive or negative) of the relationships. This system mapping approach provides a means for translating people's complex understandings and perceptions of issues into a visual format that represents the interactions and dynamics of a system.

Fuzzy cognitive maps can be used for 'what-if' scenario analysis, which enables researchers to explore the potential outcomes of changes in a system. By altering the state of a particular node or a group of nodes, researchers can observe how such changes propagate through the system and directly and indirectly impact different components of the system. Insights produced through such analysis improve understanding on the behavior of a system under different conditions and via different interventions. Such insights can be used to support decision-making and inform policy.

There are various tools available for creating systems maps, such as Kumu, Gephi, Mindmap, yEd, LOOPY, and Mental Modeler. Some of these tools, such as LOOPY and Mental Modeler, can be used for scenario analysis. This report provides a comparison of LOOPY and Mental Modeler, as tools for systems-based scenario analysis.

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[1] Vaughn, L. M., & Jacquez, F. (2020). Participatory Research Methods – Choice Points in the Research Process. *Journal of Participatory Research Methods, 1*(1). https://doi.org/10.35844/001c.13244

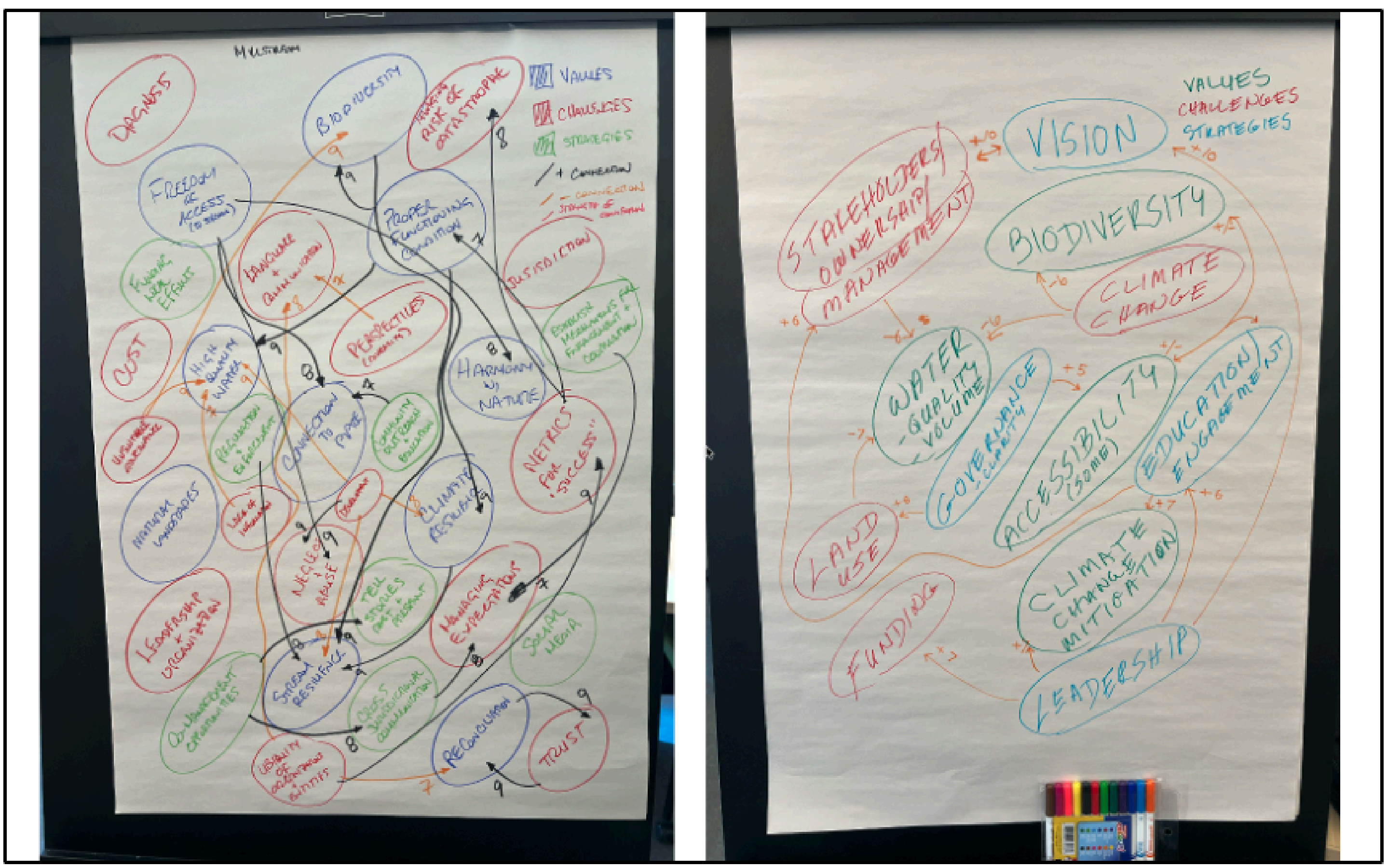
## Case Study

This study examines the use of LOOPY and Mental Modeler for creating system maps and examining systems dynamics around watershed management issues. The research focuses on the Millstream Creek Watershed, located on Vancouver Island (British Columbia, Canada). Systems components and relationships were mapped based on local stakeholder understanding of the watershed issues, as well as the stakeholders' ideas about strategies for addressing these issues.

Workshops were held that gathered 17 participants, representing local government, academia, non-governmental organizations, and other stakeholders. The participants were divided into 6 groups, and each group created a system map of major issues and concerns, social and ecological values, and potential management strategies in the watershed (Figure 1). The maps consisted of nodes, edges, and the ratings of the strengths of the relationships/edges between nodes.

After the workshops, the system maps were aggregated to create a single system map, consisting of 53 nodes and 113 edges. The system map data were imported into Mental Modeler, and also used to create a model in LOOPY. Both Mental Modeler and LOOPY were used to examine systems dynamics and to conduct scenario analysis, which enabled a comparison of the respective strengths, weaknesses, and appropriate applications of each tool.

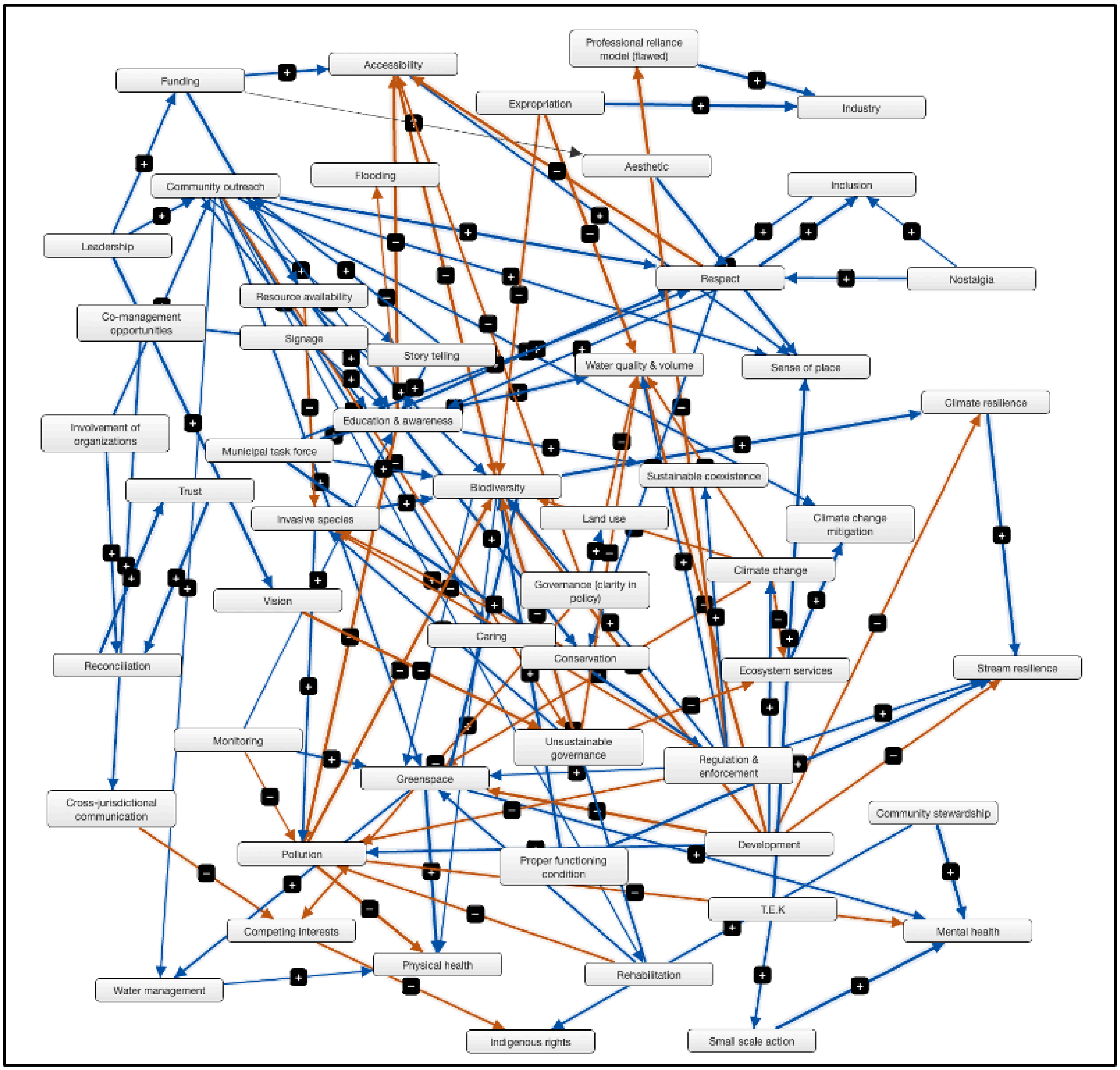
**Figure 1.** ***Systems map developed by participants during the workshop***



## Mental Modeler

Mental Modeler is a tool that is used to map, visualize, and analyze systems using stakeholder understandings of complex issues. The tool can be used to support decision-making, and it allows users to map the relationships among different elements of a system to provide a comprehensive picture of the factors surrounding an issue, as well as potential solutions for addressing the issue (Figure 2). The tool is designed to facilitate the involvement of multiple stakeholders in planning and decision-making processes by incorporating their knowledge and perspectives in system modeling exercises. Users can assign weights to system relationships to identify the strengths of an effect or influence that one system component has on another, and they can simulate different scenarios by modifying elements and relationships within the model.

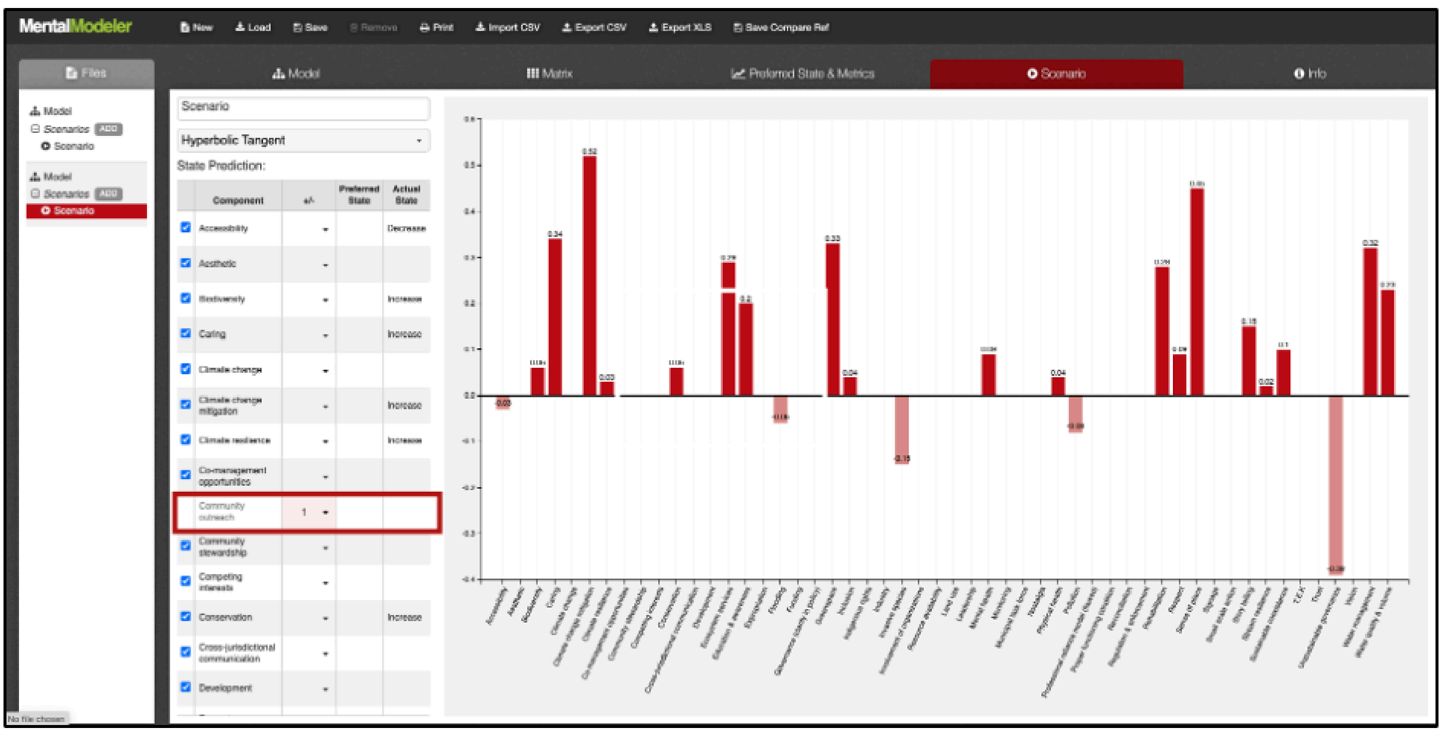
**Figure 2.** ***Systems map created on Mental Model***



Mental Modeler users import a spreadsheet file into the program, which contains an adjacency matrix. An adjacency matrix is a table of the presence and strengths of relationships between system components. Mental Modeler visualizes this matrix as a system map, where the different system elements are connected by positive (i.e., increasing, reinforcing) and negative (i.e., decreasing, balancing) edges. The tool also imports the relationship strengths data, and each edge/connection has an associated numerical value representing its strength rating.

Once the adjacency matrix is uploaded and visualized in Mental Modeler, users can perform scenario analysis. This involves 'activating' nodes by assigning a value that maximizes the strength of the node's effect on other nodes and (consequently) their impact on the system. After activating the nodes, simulations can be done to examine the scenarios and to produce graphs that show the effects and changes to the other nodes in the system under the different scenarios. The graphs illustrate which nodes increase or decrease (and to what extent) due to other nodes being activated in the system. For example, activating 'community outreach' results in positive changes to climate change mitigation, sense of place, green space, and water management, while resulting in negative changes to invasive species and water management issues (Figure 3).

**Figure 3.** ***Scenario analysis page on Mental Modeler***



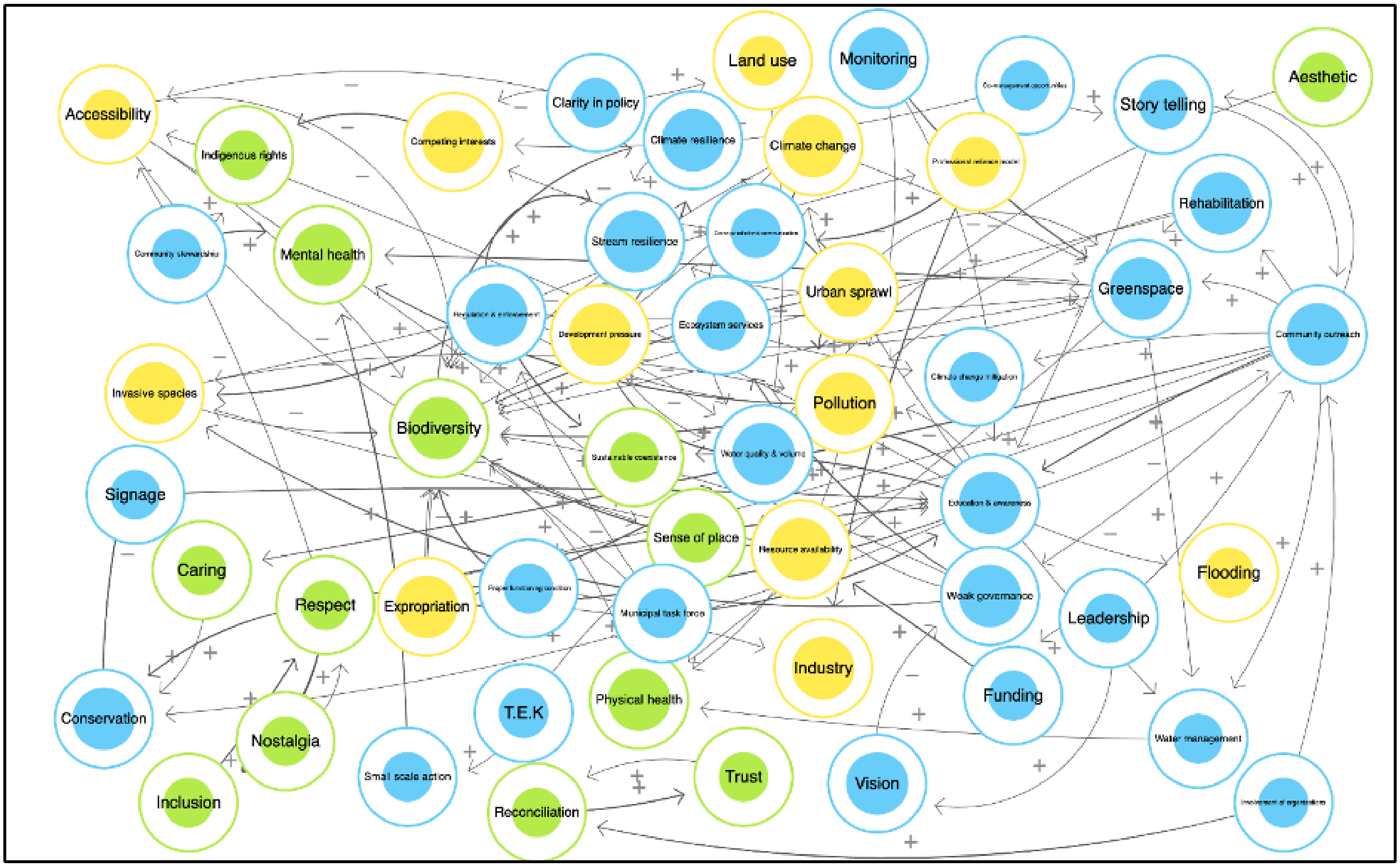
## LOOPY

LOOPY is a simple yet powerful web-based application designed to allow participants to identify nodes, draw connections, and run scenarios that dynamically illustrate systems interactions. LOOPY allows users to create interactive simulations that visually represent dynamic models of systems and their components, showing how different parts of the system influence each other over time. LOOPY can be used for scenario analyses by defining different variables or components in the system as increasing or decreasing, which allows users to explore the potential effects and outcomes of different variables on a system and (as a result) understand the impact of various interventions or changes in the system.

The process of creating a system model in LOOPY involves first drawing the nodes and edges to visually represent the relationships and interactions in the system. As done in Mental Modeler, the nature of the connections are defined as either positive or negative. After mapping the system, a LOOPY user can define the strengths of the relationships by adding more edges of the same nature (i.e., positive, negative) between nodes to amplify the effect of a node on another.

A system model developed in LOOPY represents the relationships and dynamics among the components of a complex system (Figure 4). As the number of nodes in the model increases, the direct and indirect effects of system components on other nodes become more extensive and complex. These effects are observed through system simulations.

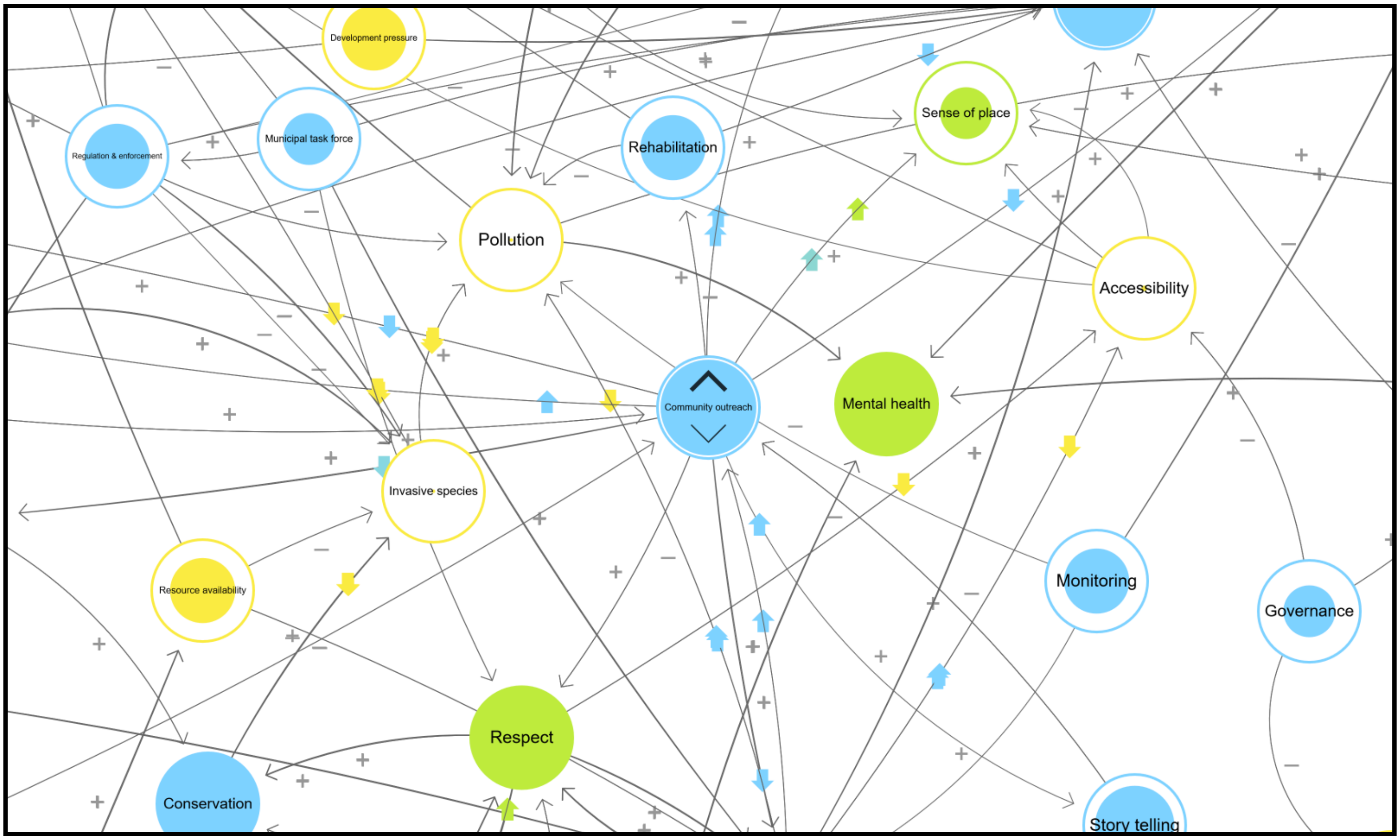
**Figure 4.** ***Systems map developed using LOOPY***



Simulations are conducted in LOOPY by selecting a node and increasing or decreasing its presence in the system. Doing such results in a propagation of arrows from the node to other nodes (Figure 5). The arrows travel through the edges/connections, and they represent the positive or negative influences/effects exerted by nodes on other nodes. LOOPY simulations are animated in such a manner that changes in directly connected nodes occur first, and then, these nodes are subsequently activated to exert effects on the nodes to which they are connected, resulting in cascading effects throughout the system.

The time it takes for a simulation to affect or activate a nodes is determined by their distance (in terms of number of connections) from the originally activated node. Nodes that are closer to the originally activated node are impacted more quickly, while those further away take longer to experience the change. In this way, LOOPY simulations illustrate how different activities, changes, and interventions in a system can ripple throughout the entire system, demonstrating the interconnected and dynamic nature of the systems.

**Figure 5. *Systems simulation in LOOPY***



## Comparison of Scenario Analysis Tools

Many system mapping and modeling tools are complicated and difficult to learn, requiring technical knowledge and expertise that present barriers for beginners and those without specialized training. Simple, easy-to-use tools, such as LOOPY, allow a broad range of people to effectively engage in systems mapping and modeling, making this form of analysis more inclusive and accessible. However, such tools may not have the same analytical power as more advanced software with more feature and functionality, such as Mental Modeler.

To explore the trade-off discussed above, a comparison of the systems dynamics and scenario analysis capabilities of LOOPY and Mental Modeler was done by activating 10 out of a total of 53 nodes in the system to observe differences (Table 1). The nodes were selected based on their high number of connections in the system. Note that the degree of impact that a node has on other nodes is not directly comparable between the two tools because Mental Modeler produces quantitative output, whereas LOOPY simulations feature outcomes in a visual manner. Therefore, the comparative analysis instead focuses on the numbers and types of nodes affected when activating a particular node.

**Table 1.** ***Comparison between LOOPY and Mental Modeler***

| Nodes | LOOPY | Mental Modeler | Difference (LOOPY - MM) | Common nodes (n) |
|---|---|---|---|---|
| Pollution | 7 | 4 | -3 | 4 |
| Invasive species | 8 | 7 | -1 | 7 |
| Weak governance | 12 | 12 | 0 | 12 |
| Development pressure | 12 | 7 | -5 | 6 |
| Education & awareness | 19 | 24 | 5 | 19 |
| Story telling | 22 | 24 | 2 | 22 |
| Signage | 25 | 24 | -1 | 23 |
| Community outreach | 24 | 24 | 0 | 23 |
| Involvement of organizations | 27 | 27 | 0 | 27 |
| Co-management opportunities | 28 | 28 | 0 | 27 |

The results from LOOPY and Mental Modeler were similar; however, the comparative analysis revealed some differences. For example, ‘pollution’ and ‘invasive species’ show slight differences in the number of nodes affected, with more nodes being affected in LOOPY in both cases. Nodes such as ‘development pressure’ and ‘education and awareness’ exhibited greater differences, with these respectively being -5 (i.e., more nodes affected in LOOPY) and 5 (i.e., more nodes affected in Mental Modeler). In many cases, activated nodes (including such as ‘involvement of organizations’, ‘co-management opportunities’, and ‘weak governance’) impacted the same number and types of nodes across both tools. This demonstrates that the tools can be used in concert for a consistent and reliable analysis of systems and scenarios.

## Conclusions

Both LOOPY and Mental Modeler are designed with user-friendly interfaces that make them intuitive and easy to use. LOOPY is perhaps more user-friendly, being a simple tool with relatively few features and functions; however, both tools offer a degree of user-friendliness. This ease of use is valuable for applying the tools in participatory planning and stakeholder engagement contexts, as the tools can be used to engage a wide range of stakeholders to effectively capture and reflect the knowledge of these people in systems and scenario analysis exercises. Both LOOPY and Mental Modeler can serve as powerful tools for facilitating workshops and group discussions. The tools can be used for active participation and engagement in workshops, as they allow users to collaboratively build and analyze system models.

The advantages of LOOPY include its simple, visual interface that can be easily understood and used by non-expert groups with little training. Its uncomplicated and aesthetic design helps to make the impact of changes within a system understandable to the users, regardless of their scientific and/or technical background. In addition, LOOPY has the ability to present cascading effects and feedback loops in a dynamic and salient manner. Through animated simulations, LOOPY can illustrate how changes in one part of the system can ripple throughout the entire system (i.e., cascading effects), as well as how the effects that a node or component exerts on system can (through a series of systems interactions) ultimately lead to the node/component being impacted itself (i.e., feedback loops). The animations in the simulations make the cause-and-effect relationships in a system visible and apparent, providing a vivid and engaging way to understand complex interactions. Such understanding can enhance the users'/stakeholders' comprehension of how to engage in systems approaches to address sustainability issues.

LOOPY simulations demonstrate effects on different nodes in a visual and qualitative manner, meaning that system effects on nodes are observed in terms of how increases or decreases in the node occur more rapidly or slowly due to the influences and effects of other nodes. This approach to simulation provides an intuitive way to interpret outcomes of system changes and interventions; however, it lacks in precision. In contrast, Mental Modeler presents quantitative output, which enables a more detailed and precise analysis. Concisely stated, Mental Modeler's strengths are that it allows for an in-depth comparative analysis of scenarios, whereas LOOPY strengths are that it presents simple, intuitive outputs which are easily understood by users.

LOOPY and Mental Modeler have their respective strengths. LOOPY's animated simulations, user-friendly design, and visual output make it particularly well-suited for engaging non-experts and facilitating broader understanding of systems issues and interactions. Mental Modeler produces detailed quantitative outputs, offering advanced analytical capabilities and the ability support rigorous research. The tools complement each other, and when used in concert, they can support comprehensive and effective participatory research and scenario analysis.