

Using *Fuzzy Cognitive Maps* for Effective Participatory Research in Agricultural Leadership, Education, and Communication

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Introduction/Need for Innovation

Contemporary agricultural problems call for innovative solutions that effectively integrate human dimensions. Modeling is an emerging tool that promotes stakeholder engagement and captures its features throughout any process or system (Papageorgiou et al., 2019). Models seek to clarify messages and communication channels among multiple interested audiences, promote careful selection of alternatives, and allow decision-makers to identify critical knowledge gaps that make model predictions suspect (Pokorny et al., 2018). *Fuzzy Cognitive Maps* (FCM) are a form of modeling based on cognitive map theory (Gray et al., 2014). According to Novak and Cañas (2008), as cited by Gray et al. (2014, p. 2), cognitive maps are “graphical representations of organized knowledge that visually illustrate the relationships between elements within a knowledge domain. The relationships between concepts in a hierarchical structure are logically defined by connecting concepts (nodes) with semantic or otherwise meaningful directed linkages.” FCMs enhance decision-making processes and applied research in several academic disciplines by integrating the knowledge of the community members and other stakeholders (Gray et al., 2013).

FCMs have been a tool used to explore various socio-environmental issues, especially when there is a need to integrate shareholders' knowledge into the decision-making process (Kafetzis et al., 2010). For example, FCMs have been implemented in governance (Shahvi et al., 2021), wildfires risk and management (Hamilton et al., 2019), coastal management (Meliadou et al., 2012), and natural disaster preparedness (Singh & Chudasama, 2017). There is a need for agricultural leadership, education, and communication (ALEC) researchers to improve participatory processes in order to address contemporary issues and implement initiatives to strengthen farming communities. Although FCMs have existed as a research methodology for some time, they are not used by ALEC researchers. Therefore, our innovative idea aims to demonstrate FCMs' potential to engage stakeholders in ALEC scholarship using our experience facilitating local climate planning with Peruvian subsistence farmers.

How it Works

FCMs have the potential to extract, combine, and represent group knowledge in complicated situations for individual analysis and between-group comparisons. To build a FCM, members of the target population must identify the topics, concepts, and themes (nodes) of the problem or system under study, identify representative nodes of the node under study, and establish the relationships (edges) between them. Participants should weigh the edges between the nodes on a scale of -1 to 1 (for example, -1= *strongly negative*, 0 = *neither negative or positive*, 1= *strongly positive*). This last process is transforming qualitative data into quantitative data (Quantitating). After the FCM is completed, it is transferred to modeling software. We used the Mental Modeler software because it facilitates decision-making in problem management or searches for solutions while preventing possible adverse results in any initiative. This software consists of three interfaces. In the first interface, the digital version of FMC is built. In the second interface, the connections established in the cognitive modeling are presented in a matrix that places the generating component of the link on the Y-axis and the receiving component on the X-axis and shows the value assigned to each edge. Changes to the FCM in the first interface will automatically appear in the second. Finally, the third interface uses an activation formula to

calculate the results derived from changes in any of the components of the cognitive model and predict the variability of the problem or system of interest.

Results to Date

Seventeen farmers participated in an agricultural climate adaptability modeling process to identify priority areas for assistance and training and to inform a local climate action plan in Peru. Participants received a briefing and training session on FCM before engaging in modeling. The participants built their FCM with a facilitator who guided them in identifying relationships between the nodes. Finally, the participants collectively evaluated and approved the final FCM. The FCM identified a complex network, including 27 farmers' priority needs for training and intervention (nodes), conditioning Peruvian farmers' potential for climate adaptability. Variability in local rain and temperature patterns, along with the lack of technical assistance, were the systems driving components. Other system nodes include water resources, climate related-knowledge, agricultural innovations, farmers' loans, and agricultural exchange. Finally, we constructed and analyzed three scenarios to demonstrate how variation in a specific system's driving components influences climate adaptability potential, and we presented and explained our study's results to members of the community and local authorities. Currently, our results guide the formulation and implementation of a local climate action plan focused on smallholder farmers in the study location.

Future Plans/Advice to Others

Our study identified farmers' priority needs for training and intervention using participant insight to effectively support agricultural climate adaptability processes. Our team is working on other research initiatives exploring climate change adaptation strategies' effectiveness and inclusiveness, disparities in climate change knowledge across demographic groups, and intervention impacts on predictions of climate-smart commodities. In addition, we are preparing multiple case studies to exemplify FCMs' potential for ALEC scholarship.

Our advice to others includes (1) considering participants' socio-demographic characteristics and cultural identities when designing the modeling sessions, (2) acknowledging participants' proficiency with electronic devices before implementing an FCM data collection, (3) implementing FCMs training with participants and researchers if they are not familiar with the modeling process, (4) giving participants opportunities to revise the final FCM, and (5) establishing open communication with participants and researchers to enhance a participatory modeling process.

Cost/Resources Needed

Although mapping methodologies, such as FCM, can be implemented without technology resources and only using conventional educational materials, the possibility of building scenarios (identifying potential changes and preventing impacts) can only be operationalized using the statistical functions of a modeling software. Therefore, we used the open-source *Mental Modeler* software. To access the *Mental Modeler* software, researchers must create a free account on the software website. In addition, all instructions and several examples of how to use the MM are available free of charge at mentalmodeler.com.

References

- Gray, S. Gray, S., Cox, L., & Henly-Shepard, S. (2013). Mental modeler: A fuzzy-logic cognitive mapping modeling tool for adaptive environmental management. Proceedings of the 46th International Conference on Complex Systems, Phoenix, AZ, USA.
- Gray, S., Mellor, D., Jordan, R.C., & Newman, G. (2014). Modeling with citizen scientists. Proceedings of 7th International Environmental Modelling and Software Society (iEMSS), San Diego, CA, USA.
- Gray, S. A., Zanre, E., & Gray, S.(2014). *Fuzzy cognitive maps as representations of mental models and group beliefs*. In E. I. Papageorgiou (Ed.), *Fuzzy Cognitive Maps for Applied Sciences and Engineering* (Vol. 54, pp. 29–48). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-39739-4_2
- Kafetzis, A., McRoberts, N., & Mouratiadou, I. (2010). *Using fuzzy cognitive maps to support analyzing stakeholders' views of water resource use and water quality policy*. In M. Glykas (Ed.), *Fuzzy Cognitive Maps* (Vol. 247, pp. 383–402). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-03220-2_16
- Meliadou, A., Santoro, F., Nader, M. R., Dagher, M. A., Al Indary, S., & Salloum, B. A. (2012). Prioritizing coastal zone management issues through fuzzy cognitive mapping approach. *Journal of Environmental Management*, 97, 56–68. <https://doi.org/10.1016/j.jenvman.2011.11.006>
- Papageorgiou, K., Singh, P. K., Papageorgiou, E., Chudasama, H., Bochtis, D., & Stamoulis, G. (2019). Fuzzy cognitive map-based sustainable socio-economic development planning for rural communities. *Sustainability*, 12(1), 305. <https://doi.org/10.3390/su12010305>
- Pokorny, J. J., Norman, A., Zanesco, A. P., Bauer-Wu, S., Sahdra, B. K., & Saron, C. D. (2018). Network analysis for the visualization and analysis of qualitative data. *Psychological Methods*, 23(1), 169–183. <https://doi.org/10.1037/met0000129>
- Shahvi, S., Mellander, P. E., Jordan, P., & Fenton, O. (2021). A Fuzzy Cognitive Map method for integrated and participatory water governance and indicators affecting drinking water supplies. *Science of The Total Environment*, 750, 142193. <https://doi.org/10.1016/j.scitotenv.2020.142193>
- Singh, P. K., & Chudasama, H. (2017). Assessing impacts and community preparedness to cyclones: A fuzzy cognitive mapping approach. *Climatic Change*, 143(3–4), 337–354. <https://doi.org/10.1007/s10584-017-2007-z>