Appendix 4. Method to generate FCM inferences.

Fuzzy cognitive maps (FCMs) use fuzzy-graph structures to represent causal relationships (i.e. directed connections) among variables (i.e. concepts) as perceived by people. The use of cognitive maps to represent people's perception of systems has its origins in politics (Axelrod 1976). Kosko (1986) modified and extended their use by applying fuzzy causal functions with real numbers in [-1,1] to the edges. The weighted edge w_{ij} from causal concept C_i to concept C_j measures how much C_i at the originating end causes or influences C_j at the other end (Kosko 1992). The sign indicates if the relationship between C_j and C_i is positive or negative. In most FCMs, weights $w_{ij} \in [-1,1]$ are specified by experts based on observation, empirical data or expert opinion.

For the FCM inference, a vector of initial state of variables C was first multiplied with the adjacency matrix of the augmented FCM, which contained all of the weights w of the connections among the variables. The state values of variables range in [0,1]. For the baseline run, the initial state vector assumed a value of 1 for each variable in the vector. Second, each element of the vector resulting from the multiplication was subjected to a logistic function to keep the values into the interval [0,1] as in Eq. A4.1. Third, the new transformed vector was multiplied again with the adjacency matrix and the elements were subjected again to transformation. This process was repeated until the system converged. The FCM inferences could also implode, explode, show cyclic stabilization, or set into a chaotic attractor (Özesmi and Özesmi 2004, Kok 2009). According to Kok (2009) the pattern can usually be determined after 20 to 30 iterations. Our values stabilized in 21 iterations.

Eq. A4.1.

$$C_i^{(k+1)} = f_i\left(C_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} C_j^{(k)} e_{ji} \right)$$

where $f_i()$ is an activation function for variable C_i using a logistic function to transform the results into the interval [0,1]. $C_i^{(k+1)}$ is the value of variable C_i at iteration step k+1, $C_i^{(k)}$ is the value of concept C_i at step k, $C_j^{(k)}$ is the value of concept C_j at step k, and e_{ji} is the weight of the causal relationship between variable C_j and variable C_i. Transformation using a logistic function was applied to better understand and represent activation levels of variables and comparison among variables (Özesmi and Özesmi 2004).

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