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Using the fuzzy cognitive map approach to promote nature-based solutions as a strategy to improve water quality in Ecuadorian communities

Kalina Fonseca^{1,3}, Alicia Correa¹, and Lutz Breuer^{1,2}

¹Centre for International Development and Environmental Research (ZEU), Justus Liebig University Giessen, Senckenbergstrasse 3, 35390 Giessen, Germany

²Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (iFZ), Justus Liebig University Giessen, Heinrich-Buff-Ring 26, 35390, Giessen, Germany

³Water Resources Management Group, Technical University of Cotopaxi (UTC), Av. Simón Rodríguez s/n Barrio El Ejido Sector San Felipe, 050104, Latacunga, Ecuador

An adequate strategy for water quality improvement in developing countries must consider the economic scarcity of water, the external factors that affect its quality, and the participation of multisectoral stakeholders in water management decisions. In addition, stronger links to nature can be established through methods inspired from nature to clean the water, such as artificial floating islands (AFI). Restoration of aquatic ecosystems with AFIs occurs as water passes beneath the floating mat and the roots of macrophytes take up metals and nutrients. In this context, we utilized Fuzzy Cognitive Maps (FCMs) to identify the principal concepts that affect water quality from different perspectives: political, economic, social, technological, environmental, and legal (PESTEL). We also theoretically explore the use of AFIs combined with different policies, to find the strategy that best adapts the local water situation.

By applying the principles of FCMs, different sources of knowledge can predict the effects of policy, and problems can be identified using the centrality index of the underlying graph theory. Thus, a two-step approach was implemented for our analysis: First, from 40 literature-based PESTEL concepts related to water quality deterioration, local experts in water management were invited to identify the most influential concepts and to include additional ones regarding the local water situation and policies to support the improvement of water quality. Second, workshops were organized, inviting members of communities to discuss the degree of cause-effect influence of the identified concepts, and also to include a water management policy, considering AFIs as one solution.

Three Ecuadorian communities distributed to cover representative ecosystems from the Pacific coast, Andean mountains, and Amazon floodplain were selected for this research, i.e. the community of *Mogollón* dominated by mangroves land cover, *Chilla chico* by páramos, and *Awayaku* by rainforest. According to the FCMs, 21 PESTEL concepts affect water quality in the páramos community and most of them are related to politics (23%) and the environment (23%). Community workshop at the same community identify that the major problem is related to natural

water pollutants. For the mangrove community, 23 concepts were identified mainly driven (47%) by environmental concepts, whereas the communities see the major water quality issue in view of human exposure to environmental pollutants. In the case of the rainforest community, 19 concepts were recognized with 40% related to economics, whereas the communities identify the principal concern being the violation of environmental legislation. Regarding the potential implementation of AFIs, the páramos community concludes that AFIs should be implemented and coupled with environmental education programs. Additionally, water-related governmental institutions should be involved during realization. The mangrove community shows interest in AFIs, when combined with payment for ecosystem services. Finally, the rainforest community do not consider AFIs as a primary solution. Instead they propose the creation of a committee to denounce violations of water quality laws and to improve the educational level of community members. In conclusion, the FCM is a powerful tool to bring together the knowledge of multisectoral stakeholders and to analyse suitable strategies for the local improvement of water quality.