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SOCIAL SCIENCE RESEARCH ON HYDROGEN
TOWARDS A CARBON-NEUTRAL UNIVERSITY DISTRICT

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Participatory modelling

Participatory research methods for sustainability – toolkit #6

Sustainability challenges require the integration of diverse knowledge types for understanding and managing social-ecological systems. Participatory modelling includes the active involvement of stakeholders in the design, development, and use of models addressing sustainability and natural resource management challenges. Participatory modelling has the potential to support learning and co-production of knowledge, and aid in processes of deliberations, decision-making, collective management, and social learning.

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Social-ecological systems are inherently complex and include diverse actors with differing knowledge, goals, interests, and values. Integration of diverse knowledge types and values of stakeholders is necessary for sustainable management of social-ecological systems. Systems models can be used to facilitate communication, exchange of knowledge, and dialogue between diverse stakeholders in order to aid in deliberative decision-making and developing a shared understanding of a system. Participatory modelling (PM) refers to "settings where non-scientist stakeholders are involved in any of the stages of the modelling process of their social-ecological systems (SES)" (Abrami et al. 2021). PM can lead to a purposeful learning process for action that engages the implicit and explicit knowledge of stakeholders to create formalized, shared, and negotiable representations of reality (Voinov et al. 2018). There are multiple strands in the use and application of PM, ranging from research to applied, social learning. PM can be more descriptive, exploratory, or explanatory than less formalized methods with similar aims such as participatory scenario planning (toolkit #3, Hamann et al. 2022). The focus can shift from the development of a model with and for stakeholders for evaluation of policy option towards a greater emphasis on the co-learning process to support collective action or collaborative governance. The degree of participation of stakeholders within the PM process can range from passive participation, where participants gain information about the model and engage with modelers in model calibration or validation, to a deeper, more active participation where stakeholders articulate and promote model design decisions and analysis and apply the learning of the participatory process to real-world decisions.

In this series, we aim to alert *GAIA* readers to useful toolkits for participatory research methods in sustainability science. If you would like to contribute a toolkit description, please contact **gaia@oekom.de**.

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Procedure

In a PM approach, meaningful engagement for all participants requires a significant degree of reflection, creativity, adaptability, and flexibility. PM uses a wide variety of methods and tools to formalize and synthesize knowledge from stakeholders. The selection of tools requires knowledge of how different tools can facilitate the formalization of stakeholder knowledge and viewpoints and careful examination of resulting trade-offs (for a detailed overview see Voinov et al. 2018). An iterative approach allows for exploration of modelling detail and adapting the process according to shared interests but can come at additional costs (Smajgl 2010, Zellner et al. 2022). Documentation on the deliberation of purpose, process, partnerships, and products is advised to increase transparency and reflection over the diverse PM processes (Gray et al. 2018). Here, we describe broadly three guiding phases for a PM approach followed by a case example of the PM workflow that explains the rationale for choosing suitable tools and methods (box 1).

***Phase 1:* Setting the scene: Defining purpose, context, stakeholders, and process facilitation**

Purpose: Defining the purpose of the PM approach requires a reflection on the reasons why modelling would be an appropriate approach for the research question, who would it be beneficial for, and why the participation of stakeholders is needed (Gray et al. 2018).

BOX 1: Example workflow of participatory modelling (PM) from a participatory project assessing various aspects of food security in West Africa

This case study example focuses on food security in Mali, West Africa and involved rural farmers, researchers and agricultural officers in Mali at various stages with varying levels of participation. At the fact-finding and knowledge acquisition stage, open-ended interviews and narratives were used to understand individual cognition and perceptions of climate risks and food security (figure 1). The interview data informed mental models of intra-household decision-making around food production and consumption (Rivers et al. 2017). The mental models subsequently inspired a participatory board game design approach where farmers co-created and played a board game called *Food and Farm* to explore agricultural decision-making under climate risk and uncertainty. This approach facilitated a dialogue between the farmers and the researchers that led to a shared systems understanding of how agricultural decisions influence food security, allowing researchers to identify the boundaries of the system, the rules that govern the system, and insights into how such rules and actions may change under climate risk and uncertainty.

Researchers then developed a causal loop diagram from the qualitative game data that allowed for an assessment of the dynamic barriers that inhibit food security and climate adaptation (Sanga et al. 2021). Data and insights from the board games as well as the causal loop diagrams were then used to develop system dynamics and agent-based models. The system dynamics model explored food security at the national level under a series of climate and adaptation scenarios (Sanga 2020). The agent-based model used insights from the game plays and the system dynamics model to explore the role of cross-scalar mechanisms of agricultural innovation on food security and income inequality in Mali. The agent-based model was used as an exploratory tool to support a reflective process with Malian researchers and agricultural officers. Collaborative storytelling and model exploration allowed researchers and participants to understand the potential consequence of alternate innovation mechanisms, and the role of innovation actors in influencing food security in Mali (Sanga et al. submitted).

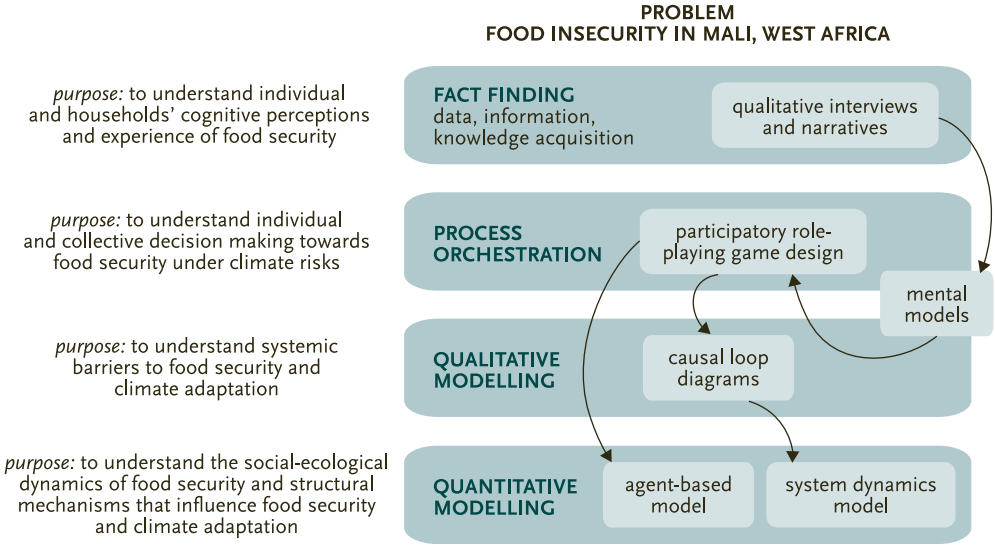

FIGURE 1: Case example of participatory modelling workflow. Workflow diagram adapted from Voinov et al. (2018, p. 235).

Context: Establishing the context of the PM approach incorporates an explicit articulation of the expectations from different participants. It requires a clear description of the system boundaries, a knowledge base of pre-existing narratives and information about the system under study as well as limitations for the participatory process (e. g. time, personnel, conflicting interests).

Stakeholders: Diverse groups of stakeholders can be involved in different steps of the PM process, but a deeper PM approach would ideally incorporate their viewpoints, needs and beliefs from the early stages of defining research goals, objectives and purpose. It is recommended to organize stakeholder discussions in heterogeneous groups in cooperative contexts and homogeneous groups for competitive contexts to ensure equitable distribution of power and influence.

Facilitation: Facilitators are essential for supporting the process design and running the participatory process, while researchers focus on observation and data collection. Objectivity and trust from participants towards the facilitator can reduce biases in the modelling process.

Phase 2: **Formalization of models**

Different modelling paradigms can be used for PM, from soft system methods such as conceptual mapping and role-playing games to more formal ones such as causal loop diagrams, fuzzy cognitive maps, system dynamics, agent-based or network analyses (see Gray et al. 2018 for an overview). Box 1 provides a case example of how different qualitative and quantitative modelling techniques and approaches can lead to a deeper understanding of complex issues when used in collaboration with research participants and stakeholders. The choice of modelling technique depends on the purpose. For example, PM for consensus build- >

ing and conflict resolution often uses visual techniques such as causal loop mapping, participatory game design, or fuzzy cognitive maps to aid stakeholders and researchers in developing a system understanding of the problem. Qualitative conceptual models may be necessary or sufficient outcomes of PM. Alternatively, more quantitative tools can also be employed for simulation that can be run by experts and participants through a model user interface or other user interactions, such as graphical information systems and cost/benefit analyses. Usually, direct results need aggregation and interpretation to be integrated into the participatory process (see examples by Smajgl 2010) but may also be aligned towards group model building, which includes stakeholders' involvement in development, parametrization and scenario testing.

Phase 3: **Collaborative reflection and debriefing**

Interpretation of the participatory models requires collaborative reflection and deliberation among stakeholders. This can be done through participatory scenario planning (toolkit #3, Hamann et al. 2022) where model simulations are refined and reiterated for collaborative reflection with stakeholders (Voinov et al. 2018). A recommended last stage for PM is participant appraisal of the method's efficacy, efficiency, and added value.

Skills and resources

- Participants should have the capacity to openly collaborate and engage at various stages of design, participation, and reflection.
- Researchers should have relevant expertise in the type(s) of modelling techniques chosen for the PM process and be able to reflect on the choice of methods and tools.
- Facilitators should be skilled in initiating and maintaining dialogue with the participants to ensure that the diversity of views and issues are captured without bias.
- A priori ethical review of the methods proposed for PM process is needed to ensure the protection and confidentiality of participants, particularly those who may be vulnerable.

Key weaknesses/challenges

- Power relations and dynamics among stakeholders within the PM process may lead to a dominance of certain perspectives at the cost of others.
- PM requires stakeholder participation, making it difficult to adhere to standardized research procedures that meet reproducibility expectations.
- In empirically rich contexts, participants may get lost in the details or complexity of the issue.
- Participants may face technical challenges in using highly quantitative models.

Key strengths/benefits

- PM can be effective in capturing experiential knowledge and social learning of decision-makers and diverse stakeholder groups.
- PM workflow can be co-designed and customized for a particular context or situation.
- PM can particularly support deliberation and exploratory analysis in contested social-ecological systems with trade-offs and conflicting activities.
- PM provides an opportunity to reflect on the research context as well as the researchers' and participants' positionality.

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