

Relevant Theoretical and Empirical Aspects for Considering Human Decision-Making Represented in Agent-Based Models for Natural Resource Management

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Summary: From a human-environment system (HES) perspective, I present theoretical and empirical aspects for considering human decision-making represented in agent-based models (ABMs) for sustainable natural resource management, which are different from those in purely social/psychological and economic ABMs.

1. MOTIVATION

Theoretically comprehensive and empirically grounded representation of land-use decisions that co-evolve with social-ecological environments over time and space remains as a key challenge of coupled human-environment system (HES) modelling for supporting sustainable land management. Despite the wide range of available theoretical and technical options for decision-making modelling, it is lacking of systematic consideration of relevant criteria required to archiving the above-mentioned task. Therefore, there is an increasing need for protocols that offer clear structures for facilitating ABM's modellers or readers to adequately *represent* and *assess* the roles of the human decision-making component in ABM with respect to specific research questions/goals.

This presentation will propose a set of criteria for completely describing human decision-making presented in agent-based model for HES, thereby to help (1) evaluating how the decision-making modelling in an ABM meets the modelling purpose as the whole and (2) identifying needs for further model development.

2. DECISION THEORIES STANDPOINTS

Given a theoretically sound protocol for human decision-making in ABMs is needed, an important question is that to what sources of knowledge the protocol should be based on. Synthesis of ways for modelling human decision-making from publications on ABMs, which have rapidly increased in the last decade, is certainly necessary. However, due to technical constraints human decision-making components encoded in precedent ABMs have been limited and the synthesis may not reflect the knowledge system offered by contemporary developmental decision/behavioural theories. Therefore, to have a conceptually "complete" structure, the protocol should be based on standpoints of common decision-making theories.

From a standpoint of common decision theories, I highlight important criteria for describing in the four key interrelated features that characterize decision-making in HES:

- (1) Decision context,
- (2) Goal and/or preference system,
- (3) Decision space (or alternatives/choices space), and
- (4) Mechanism for selection of strategies and/or actions from the alternatives space.

The description of decision context focuses on not only boundary conditions of the modelled HES, but also social-economic types of agents, the degree of their uncertainty regarding decision outcomes, human agent's aspiration/satisfaction level, and considered time horizon as these contextual factors will determine the relevance of behavioural assumptions (e.g. repetitive of past behaviour or imitating to strategy of similar peers; or rationally-reasoned or deliberative to innovation). The considered time horizon of decision process is important as it asks whether long-term and secondary feedback loops are necessarily incorporated.

The description of considered goal system distinguishes fundamental goals/preferences (e.g. livelihood strategies) from alternatives of resource allocations (e.g. labour allocation for different production activities) or resource use activities. The fundamental goals/preferences are important for determining the scope of appraisal and the desired specification of relevant attributes. Goal clearness of the modelled agents should be the key determinant for selecting appropriate approach for representing the decision mechanism: goal-free (e.g. rule-based heuristics), or goal-driven (e.g. rational or bounded-rational) traditions, or hybrid approaches that nest the two traditions. Goal clearness may be different between different agent types encoded in ABMs. For instance educated farmers may have much clearer goals than the non-educated ones. At a technical level, means for evaluating uncertainty, risks, and trade-offs in decision outcomes should be the important aspects for coaching a decision sub-model.

Well characterization of the decision space should be helpful for modellers to specify relevant methods of decision modelling. One of the common questions may be whether the decision outcome is discrete or continuous. If it is discrete the next question will be: whether the choices space is mutual exclusive or consequential.

From the standpoint of theoretical reflection for grand design concepts that are usually important for understanding complex social-ecological systems, analytical descriptions emphasize on how the modelled decision-making represent heterogeneities of social-ecological interactions, feedback loops at different orders, and the co-adaptation between human behaviour and environmental dynamics. Heterogeneity in human decision-making should be more than the diversity of agent's attributes and the social-ecological setting of the surrounding. Agent's decision context and the goal system may vary among agent types. Moreover, the alternatives space may be specific for each agent type. Adaptation of human behaviour to social-ecological changes should be considered at two levels: assimilation and accommodation (Piaget, 1983; Scholz, 2011). Assimilation refers to the modified usage of existing behaviour patterns to new situation, such as the updating of the parameters of the decision model along with social-ecological changes. Accommodation is about the development of new behavioural patterns/models or the adjustment of the agent's goal/preference system to deal more efficiently with new situations in long-term. ABMs for supporting transition of natural resource management to sustainability require the inclusion of some mechanism of accommodative adaptation in their human decision sub-models.

3. EMPIRICAL STANDPOINTS

Given the complication of the decision-making issue, together with the large sheer of available methods/techniques, protocols describing human decision-making in ABMs should give some principal guidelines for some screening assessment of the

consistency among (1) modelling goal, (2) decision context, and (3) details in design concepts and sub-models. Any effort in this tract should facilitate modellers/readers arrive at *scientifically meaningful*, and *contextually relevant* and *structural parsimonious* representation of human decision-making in ABM.

Description of tools for data collection and database, as well as methods for the calibration and validation of the encoded decision sub-models are essential for ABM's transparency and reproducibility.

The presentation will use our research results (Le et al., 2008, 2010, 2012; Feitosa et al., 2011) and some other selected publications as examples to illuminate the above-mentioned points.

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