

## Participatory modeling of social-ecological systems

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Modeling is frequently used to understand complex social-ecological systems, where the environment, actors, and interactions among them can give rise to emergent properties that would be difficult to predict by studying parts of the system in isolation. Working with stakeholders when designing the model and interpreting outcomes can increase the accuracy of the system's representation in the model, the usefulness of the model to the stakeholders, and the engagement with the model outcomes and decisions made based on them.

In this research, you will develop an agent-based or integrated model of a complex social-ecological system in the Utrechtse Heuvelrug, focusing on one of three case studies (see below). You will work with stakeholders to understand the system (actors, interactions, and processes), develop scenarios, and interpret outcomes. These can then provide insights for the non-profit Nationaal Park Utrechtse Heuvelrug, along with other stakeholders, to manage the area sustainably to support its many uses. As the challenges faced by the Utrechtse Heuvelrug are also seen in other multi-use land areas, this study can also inform efforts to address similar challenges in other systems and regions.

Some background about the Utrechtse Heuvelrug: The Utrechtse Heuvelrug consist of 20.000-hectare consecutive forest and heathland, with an additional 20.000 hectares of along the flanks. The Southern part of the Heuvelrug, an area of 10.000-hectare, has the official status of National Park. Nationaal Park Utrechtse Heuvelrug (<https://www.np-utrechtseheuvelrug.nl/>) was founded to protect and preserve the unique nature, landscape, and cultural heritage of this, in collaboration with landowners, municipalities, the Province of Utrecht, and other stakeholders.

There are three topics of particular interest to Nationaal Park Utrechtse Heuvelrug from which you can choose, but each of these can be adapted to fit your research interests:

- **Human-wildlife interactions:** Increased recreation can lead to more human-wildlife conflicts that can have a negative impact on nature. Especially flight animals, like deer, are sensitive to disturbance. It is expected that different forms of recreation, like mountain biking, cycling, walking with/without dogs on/without a leash, will have a different impact on nature through complex human-wildlife conflict mechanisms, as well as the routing system that is in place for these different recreational groups. Here, modeling could be used to integrate spatial data, behavioral ecology of wildlife species, and activity patterns and decision-making of recreational groups, to explore ways to alleviate impacts on wildlife and transition to more sustainable recreation.
- **Water extraction:** The changing climate comes with multiple challenges. The current extreme dry seasons cause costly damage to forest, nature, and land in the natural areas, and to a lesser extent, the rural areas within the Utrechtse Heuvelrug. As the natural areas on the higher parts of the Utrechtse Heuvelrug cannot reach groundwater levels, they are entirely dependent on rainwater availability. These long periods of drought are very likely linked to climate change, and therefore will become more frequent. However, multiple groups, including farmers and the municipality, also rely on water extracted from the Utrechtse Heuvelrug. Modeling could incorporate land use and topology, rainfall patterns, plant ecology, and decision-making of different actors and groups, to better understand rainwater dependencies and how to manage water use in the area to protect the forests.

- Sustainable mobility: During the pandemic there was a drastic increase in visitors and recreationists in the National Park. The present numbers in natural areas of the Utrechtse Heuvelrug were not expected for another 10 years. We strive to sustainable recreation in this area, from which the journey from and to the National Park plays an important role. Most visitors come by car – alongside increased energy consumption, this can lead to conflicts between visitors and among visitors and wildlife. Here, modeling would be used to connect spatial data on park access points and mobility, visitor decision-making, and possibly wildlife behavioral ecology to explore options for enabling more sustainable ways of visiting the Utrechtse Heuvelrug.

## References:

*Social-ecological models (just a few examples, feel free to contact me for other recommendations)*

- Marley *et al.* (2017) Does human education reduce conflicts between humans and bears? An agent-based modelling approach. <https://doi.org/10.1016/j.ecolmodel.2016.10.013>
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- Martin & Schluter (2015) Combining systems dynamics and agent-based modeling to analyze social-ecological interactions – an example from modeling restoration of a shallow lake. <https://doi.org/10.3389/fenvs.2015.00066>

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