Master's Topics 2024 to 2025

Supervised by Ilona M. Otto:

Social tipping dynamics

Qualitative and semi-quantitative case studies on bottom up changes, local and regional initiatives aiming to reduce greenhouse gas emissions. Involving themes such as change agents, leadership, cooperation, human agency, power of small groups. Could also involve non-European initiatives.

Greenhouse emissions of the wealthy

Studies on environmental and climate attitudes of very wealthy individuals as well as individuals with high agency (e.g. influencers, celebrities, etc.). Could also include other environmental impacts (e.g. nitrogen or phosphorus pollution, the use of rare metals, etc).

Co-benefits of climate policies on human health and wellbeing

Studies on how climate policies such as active mobility, co-housing, lower consumption, improved air quality, etc. influence human physical and mental health.

Indigenous approaches to nature

Studies on indigenous approaches to ownership, free riding, equality, and justice.

Misinformation and manipulation in social media

Studies involving qualitative content analysis of social media, in particularly channels and users spreading misinformation and manipulative messages.

Co-supervised by Andrew Ringsmuth:

All of the following projects can be tailored, divided or even combined, to suit student interests. Students are also encouraged to propose their own project ideas related to these topics.

1. **Modelling degrowth scenarios in a biophysical economic model using system dynamics**

Biophysical economics acknowledges that real-world economies are physical as well as social systems and exist far from thermodynamic equilibrium. Recently, progress has been made on developing biophysical macroeconomic models that couple economic and physical dynamics. This project will aim to first reproduce one of these models and then

use it to study degrowth transformations under social, economic and physical constraints.

2. **Adapting physiological network models to study sociometabolic transformations**

Bringing global society back within the planetary boundaries requires a radical transformation of societal metabolism. Existing approaches are based mainly on economic theory that largely ignores biophysical reality. Nonetheless, social-ecological systems obey the same thermodynamic principles as organisms and rapid metabolic transformations have been well studied in the latter. Can we learn new principles and strategies for sociometabolic transformation by adapting models of organismal physiology to societies? One approach to this project would be to start by studying simple reaction-diffusion models on networks and then introduce multiscale regulatory mechanisms. An interesting research question is: How can metabolic regulation mechanisms be coordinated across scales to achieve adequately fast systemic metabolic transformation?

3. **Evolving global sustainability: modelling the emergence of sustainable common-pool resource management through multilevel cultural evolution**

Human society currently faces strong selective pressure from multiple collective action problems. It has been argued that multilevel cultural evolution provides a general theory with which to understand and model societies as they attempt to act collectively. This project will extend pre-existing work studying the conditions under which sustainable collective behaviour can evolve from selective pressures within and between social groups that must harvest natural resources for their survival. The central research question is whether and how it is possible for low-metabolism (degrowth) groups to survive and thrive when competing with high-metabolism groups.

4. **Can common-pool resource management succeed at large scales?**

This project will extend an existing agent-based social-ecological network model to study the scaling behaviour of common-pool resource management by social pressure. Do Ostrom's core design principles apply at large as well as small scales, or does social network complexity necessitate additional management systems? This may provide a natural link between resource management practices in small local communities and the emergence of markets and formal institutions at larger scales. Is there some critical scale at which the core design principles fail and additional mechanisms become necessary? Where is that scale? We will try to identify it with our model.

5. **Quantifying emergence and causation across scales in social-ecological systems**

A long-standing challenge in social-ecological systems science is to characterise so-called cross-scale interactions: the interdependencies between individuals, local communities, regional groups of communities, nations and the world as a whole. Recently, progress has been made on methods that combine dynamical systems theory with information theory to quantify how the causal power of complex systems changes with scale of organisation. This project will use these tools to provide the first quantification of cross-scale interactions in a social-ecological network model.

6. **Quantifying parallels between global civilisation and cancer biology**

Various authors have argued that, since the agricultural revolution, human societies have shown numerous features that closely parallel the growth and behaviour of cancer in an organism. In this project we will take this hypothesis seriously and explore its validity by studying multiple lines of empirical and theoretical evidence. This may provide insights into a general class of cancer-like system behaviours that are observable across a range of systems from organisms to ecosystems. The ultimate goal is to determine whether/how the enormous literature on cancer biology and medicine can provide useful clues for how to more effectively deal with sustainability challenges. This could be a purely literature-review project or could also include modelling.

7. **Ostrom vs. Lotka: The biophysics of cooperation**

Biophysicist Alfred Lotka argued that ecosystems obey a 'maximum power principle' (MPP): species which harvest the most useful energy from their environment per unit time will tend to dominate the ecosystem. Political scientist Ellinor Ostrom studied numerous societies that seemed to violate the MPP: they developed social institutions that enabled them to constrain their resource consumption rate instead of maximising it. In this project we will study this tension and attempt to situate it within broader biophysical and evolutionary theory. Depending on student interest, we can focus entirely on literature review or also develop a model aimed at studying cases in which violating the maximum power principle conveys evolutionary advantage.

8. **Quantifying micro-macro relations in social-ecological tipping using multiscale analysis methods**

There is currently great enthusiasm for the potential of social tipping phenomena to help avert undesirable ecological tipping phenomena. Such phenomena necessarily involve interrelations between individuals, communities and communities of communities, so raise the question of how to understand these micro-meso-macro relations. Indeed, the study of threshold phenomena in simpler physical systems has revealed that relating behaviour between scales of organisation in the system is essential for understanding how macroscopic tipping can emerge from small changes at the microscopic level. However, detailed application of these methods to complex systems has proven

challenging. This project will use a method called renormalization, in combination with differential geometry, to study and quantify the multiscale structure of multilayer social-ecological networks. The goal is to provide a basis for truly multiscale modelling of social-ecological systems in which social and ecological scales can be combined in a coherent way. This may enable more rigorous modelling of social-ecological tipping across scales, helping us to better understand these important and mysterious phenomena.

9. Developing methods for fractal agent-based modelling

Closely related to the previous project is the challenge of understanding fractal (multiscale, self-similar) agency. That is, how does individual agency (decisions leading to behaviour that intervenes on the world) relate to collective agency at local, regional, national and global levels? Agent-based modelling (ABM) has proven very useful in understanding social-ecological system dynamics but ABMs typically involve only two scales: individual and global. How can we develop ABMs that include the fractal agency dynamics observed in the real world? This is a big question. However, some early progress has recently been made and in this project we will build on this progress further. Depending on student interests, the focus can be on fundamental theory of agency and modelling, or applied model development.

10. Making sense of long-range correlations in complex social-ecological systems

One puzzling and important phenomenon in social-ecological systems is so-called 'teleconnections' or 'telecouplings': strong dependences between system elements that are separated by large intervals in space and/or time. For example, demand for meat in Europe this year can strongly influence Amazonian deforestation next year via international trade links. Coherent and general theory of teleconnections remains elusive; they are typically studied and modelled in an ad hoc way. However, it is well known that such long-range correlations are a common feature across a wide range of complex systems. This project will ground these highly complex teleconnections in the study of similar long-range correlations in simpler systems from physics, chemistry and biology. By situating this SES phenomenon within a larger scientific tapestry, we will aim to provide new perspective and tools for making sense of teleconnections in social-ecological systems.