Multi-Objective Spatial Optimization for Sustainable Landscape Design

Background
Sustainability has a multitude of dimensions, reflected by the sustainable development goals. Designing sustainable landscapes thus implies accounting for multiple objectives, which may be compatible or may conflict with each other (Figure 1). For example, reaching zero hunger (SDG 2) in a certain area may conflict with maximizing life on land (SDG 15), through deforestation by cropland expansion.

Computational methods
Quantifying synergies and trade-offs between these objectives can serve the landscape-design process. Multi-objective spatial optimization methods offer this quantification. Our work is in 1) the representation of space in such methods, 2) the consideration of uncertainty in the spatial input data, and 3) the integration of geosimulation and spatial optimization methods.

Representation of space
Genetic algorithms are the most commonly used multi-objective optimization methods. To apply them to spatial optimization problems, spatial arrangements (phenotype) need to be denoted by chromosomes (genotype). This brings about challenges to keep spatial relations intact in optimization processes, when cross-over and mutation alter the chromosomes (Figure 2).

Consideration of uncertainty
Spatial data contain uncertainty, which propagates to the Pareto front. We quantify uncertainty in a Pareto front by finding the extreme lower and upper bound of optimal values in the objective space: a Pareto interval (Figure 3). Spatial similarity between solutions in the interval shows the resulting landscape design uncertainty (Figure 4).

Integration of geosimulation and spatial optimization
Geosimulation modelling simulates the future state of a system under predefined (feasible) scenarios. An impact assessment can be applied to compute the sustainability of these states. However, the rest of the solution space remains unknown (Figure 5). In contrast, multi-objective spatial optimization finds states with minimal impact. Yet, it does not tell whether these states are feasible to reach. Integrating both approaches resolves these weaknesses.

References
